VTT Technical Research Centre of Finland

FDS+Evac – Technical Reference + User's Guide

(FDS 5_RC6, Evac 1.10)

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1 Introduction

This document describes, how one does an egress calculation by using the Fire Dynamics Simulator (FDS) [3, 4] developed at National Institute of Standards and Technology (NIST) and the evacuation module [1, 2] developed at VTT Technical Research Centre of Finland. This combined fire and evacuation simulation program is called as FDS+Evac in this document. The basic algorithm behind the egress movement is to follow each person by an equation motion, i.e., do some kind of an artificial molecular dynamics for humans. The forces acting on humans are both physical forces, like contact forces and gravity, and psycholigical forces exerted by the environment and other humans. This approach allows each person to have its own personal properties and escape strategies, i.e., persons are treated as autonomous 'agents'. The model behind the movement algorithm is the social force model introduced by Helbing [6, 7, 8, 9] and the modification of the model to a better description of a human body by Langston *et al.* [10]

Humans are modeled as ellipses moving in a 2D geometry. Actually, the elliptical shape of the human body is approximated by three overlapping circles, see Fig. 1, just like in the Simulex program [11, 13, 14, 15] and in the MASSEgress program [12]. The body dimensions and the unimpeded moving speeds of typical human population types are shown in Table 1. The body diameters and walking speeds are drawn randomly for each generated human from uniform distributions, whose widths are also given in the table. The body diameter and moving speed distributions are taken to be same as in the Simulex program [11, 13, 14, 15] for the Male, Female, Child, and Elderly categories. The category Adult is just a simple superposition of the Male and Female categories.

Table 1: Unimpeded walking velocities and body dimensions in FDS+Evac. The offset of shoulder circles is given by $d_s = R_d - R_s$, for the definition of the other body size variables, R_d, R_t, R_s, see Fig. 1.

Body type	R_d (m)	R_t/R_d (-)	R_s/R_d (-)	d_s/R_d (-)	Speed (m/s)
Adult	0.255±0.035	0.5882	0.3725	0.6275	1.25±0.30
Male	0.270±0.020	0.5926	0.3704	0.6296	1.35±0.20
Female	0.240±0.020	0.5833	0.3750	0.6250	1.15±0.20
Child	0.210±0.015	0.5714	0.3333	0.6667	0.90±0.30
Elderly	0.250±0.020	0.6000	0.3600	0.6400	0.80±0.30

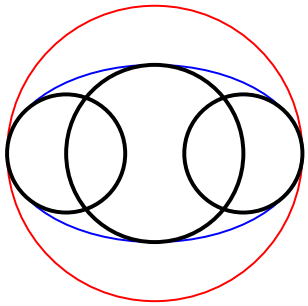

Figure 1: The shape of the human body is approximated by a combination of three overlapping circles. Shown are also the definitions of the body size variables.

1.1 Getting Started

The evacuation method developed at VTT is implemented as subrutines of the FDS5. Thus, the running of FDS+Evac evacuation simulation is done similarly as an ordinayry FDS5 fire simulation, see the FDS User's Guide [4] for details. FDS+Evac uses also Smokeview [5] to visualize the results and also the computer hardware requirements are similar with FDS. Note, that for now FDS+Evac can only be run on a single processor mode, i.e., one can not use multiple processors. Work is in progress to enable the calculation of the smoke and toxic gas consentration using multiple processors so that these can be later read in when doing a single processor evacuation calculation.

The evacuation module, FDS+Evac, is embedded in the FDS (Version 5), which could be obtained from the URL

`http://www.fds-smv.net/`

Download the latest version of FDS-Smokeview and install it. The resulting FDS single processor executable is also the executable of the evacuation calculation module.

The homepage of FDS+Evac is

`http://www.vtt.fi/fdsevac`

and this page contains the combined Technical Reference and User's Guide of FDS+Evac and some examples on the use of FDS+Evac. This web site is also used to store the validations and verification test cases including the input files.

1.2 Special Features

FDS+Evac is under construction. For now, it is best suited to do calculations of buildings, whose floors are horizontal. Sports halls with spectator stands or concert halls can also be modeled. It is also assumed that the different levels of the building are separated from each other, i.e., they are connected to each other by stairs, escalators, doors, and similar objects. Wide stairs or inclines can also be used to connect different floors, but this is not as straigthforward as to use the default stairscase model. There are no merging flows allowed in the default staircase model, so FDS+Evac is not yet easy to use for tall buildings. The staircase algorithm is still very simple and it should not be trusted too much if the stairs get crowded. At this point this is not a problem, because there are no merging flows in the corridor/stairs, i.e., the exit door at the floor restricts the flow to the corridor quite efficiently. If merging flows are needed to simulate staircases then the detailed geometry of the staircase could be modeled, but this is not usually very practical way of doing things.

The evacuation calculation needs in addition to the fire calculation meshes its own 2D evacuation meshes. If no fire related data is needed in the evacuation calculation then there are no need for fire meshes and FDS+Evac can be run in an "evacuation trial" mode. One should choose the dimension and mesh cell sizes of these evacuation meshes such that the position of different evacuation specific objects, like `DOOR`, `EXIT`, is easy to give. This means that the Δx and Δy should be some nice round figures. The present version of FDS+Evac does not move these kind of objects to the mesh cell boundaries, like is done for the standard FDS fire simulation geometrical objects, like `OBST`, `HOLE`, and `VENT`. Evacuation meshes should not be too fine, because then one might face problems with the evacuation flow fields, which are used to guide human movement towards the exits. This dificulty can be addressed by an experience user, but an easier way is always to use evacuation meshes, which are not too fine. Usually mesh cell sizes 0.25 m or more can be used without any problems. For example, if you have 1.2 m wide doors you could use 0.3 m, 0.6 m, or 1.2 m cell spacing depending on how detailed geometry is needed. Note, that Smokeview does not

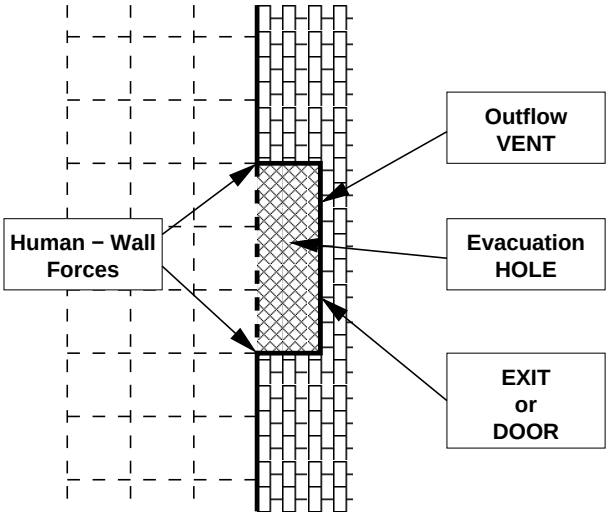

Figure 2: How to make an exit or a door.

yet fully support the evacuation calculation, *e.g.*, the positions of doors, stairs and other evacuation objects are not shown by Smokeview.

A door should be defined such that it is a little bit inside a wall, see Fig. 2. This way door casings will produce forses on humans. One should make a small hole in the wall, where an exit (or a door) is put. Note, that the width of the exit will depend on your mesh resolution. One should define the exit such wide, that it will cover the whole width of the hole. Because the obstacles are put in the mesh but the exits (or doors) are not, be sure that exits are wide enough. (Use Smokeview and activate mesh lines.) It does not matter if the end points of the exits (or doors) are somewhat inside solid obstacles.

For now, FDS+Evac has limitations on the number of humans, which can be in the same main evacuation mesh. The program stops and writes out an error message if more than 10000 humans are tried to put to the same evacuation mesh. Usually, one main evacuation mesh extends over a whole floor of the building. There may be many main evacuation meshes, e.g., different floors of the building, in the FDS+Evac calculation and the total number of humans is not restricted by the program, the only limit is the available computer memory. The user should know that if there is more than a couple of thousands humans on an evacuation floor then the calculation is going to be CPU expensive.

FDS+Evac enables coupled fire and evacuation simulations. The evacuation part uses smoke and gas consentrations from the fire calculation to affect the movement and decision making of the evacuating humans. In principle, the coupling could be made also to the other direction, i.e., humans are influencing the fire calculation, e.g., by opening doors, but this feature is not yet implemented in FDS+Evac. Concentrations of O_2, CO_2, and CO are used to calculate Purser's Fractional Effective Dose (FED) concept [16], which is used to incapasitate humans. Smoke density is used both to slow down walking speeds of humans and to affect the exit selection algorithm of humans. Smoke density can also be used to detect the fire, but is should be kept in mind that human nose is a very delicate instrument and the levels of smoke consentration needed for a sensation of smoke are well below the prediction capabilities of the current FDS fire model.

The evacuation part of the FDS+Evac is stochastic, i.e., it uses random numbera to generate the initial positions and properties of humans and there are also a small random force on each human's equation of motion. Thus, same results are not obtained for a given input file if multiple simulations are done. For this reason, one should always do a dozen or so egress simulation to see the variation of the results. For this reason, it is made posible to do many egress calculation per one fire simulation. Also the calculation of the evacuation flow fields used to guide human movement need to be calculated only once to each given

geometry.

The present version of FDS+Evac does not use optimally computer memory and does not support parallel CPU calculations. In later versions of the program, the memory usage is more optimal and also the fire simulation part can be run using parallel CPUs to produce smoke and gas concentration informtion to the evacuation part.

2 Model Documentation

This section provides a short description of the evacuation module of the Fire Dynamics Simulator (FDS). Detailed information about FDS can be found in its documentation and more detailed information about the evacuation algorithm can be found in the next section.

2.1 Name and Version of the Model

The name of the underlaying fire simulation program is the NIST Fire Dynamics Simulator or FDS. FDS is a Fortran 90 computer program that solves the governing equations of fluid dynamics, and Smokeview is a companion program written in C/OpenGL programming language that produces images and animations of the results. The evacuation calculation module developed at VTT is implemented as subroutines of FDS and these subroutines together with the FDS are called as the FDS+Evac. The present version of FDS+Evac is build on the FDS version 5.0.0 and it is the second version of the evacuation module and, thus, its version number is 1.10, i.e., FDS5+Evac1.10. Changes in the version numbers correspond to major changes in the physical models or input parameters. For minor changes and bug fixes, incremental versions are released, referenced according to fractions of the integer version numbers. In addition, day-to-day bug fixes made in response to user feedback are referenced by a compilation dates that are printed at the top of the diagnostic output file.

2.2 Type of the Model

FDS+Evac is an combined agent-based egress calculation model and a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow, where the fire and egress parts are interacting. FDS+Evac can also be used just to calculate the egress problem without any fire-driven fluid flow calculation.

2.3 Model Developers

The evacuation module of FDS was developed and its currently maintained by the VTT Technical Research Centre of Finland (VTT). A substantial contribution to the development of the mode and its implementation as a module of FDS was made by the Fire Research Division in the Building and Fire Research Laboratory at the National Institute of Standards adn Technology (NIST). Additional contributors and co-workers are cited in the Acknowledgments.

2.4 Relevant Publications

Each version of FDS+Evac is documented by this publication – the FDS+Evac Technical Reference and User's Guide. The User's Guide part of the publication the mechanics of using the computer program. The Technical Reference Guide part provides the theory and algorithm details, plus a description of the verification and validation studies and details about hte many parameters of the evacuation model and their default values.

The model behind the movement algorithm of FDS+Evac was introduced by Helbing *et al.* [6, 7, 8, 9]. The implementation of this algorithm inside the FDS program environment was introduced by Korhonen, Hostikka, and Keski-Rahkonen [1]. Later the model was modified along the lines given in the paper by Langston *et al.*[10] to a three circle representation of humans [2].

2.5 Input Data Required to Run the Model

All of the input parameters required by the evacuation part of FDS+Evac to describe a particular scenario are conveyed via one text file, which is the same that is used for FDS, created by the user. For the fire-driven fluid flow related parameters, see the FDS documentation. The input file of FDS+Evac is such that it can be used without any modifications to run an ordinary FDS calculation, i.e., FDS is neglecting all evacuation related parameters, which are present in the input file.

A complete description of the input parameters required by the evacuation module of FDS+Evac can be found in the FDS+Evac User's Guide part of this document.

2.6 Model Results

FDS+Evac computes the position, the velocity, and the dose of toxic gases of each human inside the computational domain at each discrete time step. The movement of humans can be visualized after simulation using the Smokeview program. The number of humans gone through different parts of the evacuation scenario as well as the number of humans in different nodes are saved in simple, comma-delimeted text file, that can be plotted using a spreadsheet program. Some additional, quite detailed, information are written to the diagnostic standard error channel, which could be redirected to the hard disk.

2.7 Uses and Limitations

Although FDS+Evac can address many egress scenarios, there are limitations in all of its algorithms. Some of the more prominent limitations of the model are listed here.

Geometry: The efficiency of FDS is due to the simplicity of its rectilinear numerical grid. This can be a limitation in some situations where certain geometric features do not conform to the rectangular grid. The numerical grids used by the movement algorithm of FDS+Evac are a two-dimensional cut offs the FDS grids, thus the same limitations apply to the evacuation part of the code. The present version to the evacuation module can also treat inclines, like wide stairs and spectator stands, which are along the x or y direction of the underlaying rectangular mesh. The grid cell size determines the finest details which can be modelled by the program and the geometry of the building is discretized, e.g., the widths of the doors are integral multiples of the grid cell sizes.

Reduced Visibility: The smoke consentration calculated by the FDS is used to slow down human movement using the results of a recent experiment by Frantzich and Nilsson [17], where larger smoke consentration were used than in the experiments by Jin [18]. There are large scatter in the experimental results and more experimental results are more than welcome. The default model for stairs does not include the option for humans to turn back when the smoke consentration becomes too high.

Incapacitation: The incapacitation model used the FED consept introduced by Purser [16], but the large scatter between different humans is not taken into account in the current version of the program. Whereas FDS is doing well for the smoke transport and the prediction of O_2 levels, it does much worse on the prediction of the CO concentration. In the standard mixture fraction model of FDS, the amount of CO produced is decided by the user input.

Exit Route Selection: The exit door algorithm is still a relatively simple one. It does not include any kind social interactions, like herding behavior. The user has also more or less full control on the doors which different human groups will be using. In some applications this can be listed as a benefit of the model, but this leaves too much trust on the user's expertise and/or intentions.

Detection and Reaction Times: The pre-movement time of the evacuating humans is decided by the user input by giving distributions for the detection and reaction times. In addition to the detection time given user input, the local smoke consentration can be used to trigger the detection.

Applications: There is no model for elevators in the current version of the FDS+Evac. Nor there is any specific objects relevant to maritime applications. Concert halls and sport facilities may be difficult to model due to the limitations dictated by the rectangular computational mesh.

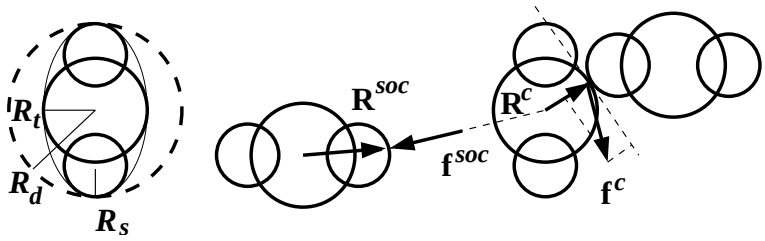

Figure 3: Definitions of the human dimensions and the radial vectors $\mathbf{R}^c$ and $\mathbf{R}^{soc}$.

3 Theoretical Basis for the Evacuation Model

3.1 Introduction

As said, the method of Helbing's group is used as the starting point of the human movement algorithm of FDS+Evac. This model is shortly described below. For a longer description, see the papers by Helbing's group [6, 7, 8, 9] and references therein. For the modification of the one-circle representation of a human to a three-circle one, see the papers by Langston *et al.* [10] and Korhonen *et al.* [2]

3.2 Human Movement Model

FDS+Evac uses the laws of mechanics to follow the trajectories of the humans during the calculation. Each human follows his/her own equation of motion:

$$m_i \frac{d^2\mathbf{x}_i(t)}{dt^2} = \mathbf{f}_i(t) + \boldsymbol{\xi}_i(t) \,, \tag{1}$$

where $\mathbf{x}_i(t)$ is the position of the human i at time t, $\mathbf{f}_i(t)$ is the force exerted on the human by the surroundings, m_i is the mass, and the last term, $\boldsymbol{\xi}_i(t)$, is a small random fluctuation force. The velocity of the human, $\mathbf{v}_i(t)$, is given by $d\mathbf{x}_i/dt$. FDS+Evac treats humans as combination of three elastic circles moving on a two-dimensional plane [10]. These circles are approximating the elliptical shape of the human body similarly as in the Simulex model [11] and in the MASSEgress model [12], see Fig. 3. The default body dimensions and the unimpeded walking speeds of different predefined human types of FDS+Evac are listed in Table 1.

The force on human i has many components:

$$\mathbf{f}_i = \frac{m_i}{\tau_i}\left(\mathbf{v}_i^0 - \mathbf{v}_i\right) + \sum_{j\neq i}\left(\mathbf{f}_{ij}^{soc} + \mathbf{f}_{ij}^{att} + \mathbf{f}_{ij}^{c}\right) + \sum_{w}\left(\mathbf{f}_{iw}^{soc} + \mathbf{f}_{iw}^{c}\right) + \sum_{k}\mathbf{f}_{ik}^{att} \,, \tag{2}$$

where the first sum describes human–human interactions, the sum over w describes human–wall interactions, and the last term, $\mathbf{f}_{ik}^{att}$, may be used for other human–environment interactions, like the fire–human repulsion. The first term on the right hand side describes the motive force on the evacuating human. Each human tries to walk with his/her own specific walking speed, $v_i^0 = |\mathbf{v}_i^0|$, towards an exit or some other target, whose direction is given by the direction of the field $\mathbf{v}_i^0$. The relaxation time parameter τ_i sets the strength of the motive force, which makes a human to accelerate towards the preferred walking speed.

The human–human interaction force in Eq. 2 has three parts. For the social force term, $\mathbf{f}_{ij}^{soc}$, the anisotropic formula proposed by Helbing *et al.* [8] is used

$$\mathbf{f}_{ij}^{soc} = A_i e^{-(r_{ij}-d_{ij})/B_i}\left(\lambda_i + (1-\lambda_i)\frac{1+\cos\varphi_{ij}}{2}\right)\mathbf{n}_{ij} \,, \tag{3}$$

where r_{ij} is the distance between the centres of the circles describing the humans, d_{ij} is the sum of the radii of the circles, and the vector $\mathbf{n}_{ij}$ is the unit vector pointing from human j to i. For a three circle representation of humans, the circles used in Eq. 3 are those circles of the two humans, which are closest to each other. The angle φ_{ij} is the angle between the direction of the motion of human i feeling the force and the direction to the human j, which is exerting the repulsive force on human i. The parameters A_i, B_i, and λ_i could be different for each human but in the present version of FDS+Evac they have same values for each human. The psychological wall–human interaction, $\mathbf{f}_{ij}^{soc}$, is treated similarly, but values A_w, B_w, and λ_w are used for the force constants. The physical contact force between humans, $\mathbf{f}_{ij}^{c}$, is given by

$$\mathbf{f}_{ij}^{c} = \left(k(d_{ij} - r_{ij}) + c_d \Delta v_{ij}^{n}\right) \mathbf{n}_{ij} + \kappa(d_{ij} - r_{ij}) \Delta v_{ij}^{t} \, \mathbf{t}_{ij} \ , \tag{4}$$

where Δv_{ij}^{t} is the difference of the tangential velocities of the circles in contact, Δv_{ij}^{n} is the difference of their normal velocities, and vector $\mathbf{t}_{ij}$ is the unit tangential vector of the contacting circles. This force applies only when the circles are in contact, i.e., $d_{ij} - r_{ij} \geq 0$. Note, that Eq. 4 contains also a physical damping force [10] with a damping parameter c_d, which the original model by Helbing *et al.* does not have. This parameter reflects the fact that the collision of two humans is not an elastic one. The physical wall–human interaction, $\mathbf{f}_{iw}^{c}$, is treated similarly and same force constants are used. The term $\mathbf{f}_{ij}^{att}$ can be used to describe attraction (or repulsion) between humans, like a herding behaviour or an adult–children interaction. It could also be used to form pairs of humans, e.g., describing a fire fighter pair entering the building. All of the force terms in Eq. 2 are relatively short ranged and they need a line-of-sight connection. Longer ranged forces could be taken in to account by changing the preferred walking velocity field $\mathbf{v}_i^0$.

Equations 1–4 describe the translational degrees of freedom of the evacuating humans. The rotational degrees of freedom are treated similarly, i.e., each human has his/her own rotational equation of motion:

$$I_i^z \frac{d^2 \varphi_i(t)}{dt^2} = M_i^z(t) + \eta_i^z(t) \ , \tag{5}$$

where $\varphi_i(t)$ is the angle of the human i at time t, I_i^z is the moment of inertia, $\eta_i^z(t)$, is a small random fluctuation torque and $M_i^z(t)$ is the total torque exerted on the human by its surroundings

$$M_i^z = M_i^c + M_i^{soc} + M_i^{\tau} \ , \tag{6}$$

where M_i^c, M_i^{soc}, and M_i^{τ} are the torques of the contact, social and motive forces, respectively.

The torque of the contact forces is calculated as

$$\mathbf{M}_i^c = \mathbf{R}_i^c \times \mathbf{f}_{ij}^c \ , \tag{7}$$

where $\mathbf{R}_i^c$ is the radial vector which points from the centre of human i to the point of contact. In FDS+Evac, also the social forces exert torques on humans and these are given by the formula

$$\mathbf{M}_i^{soc} = \mathbf{R}_i^{soc} \times \mathbf{f}_{ij}^{soc} \ , \tag{8}$$

where only the circles, which are closest to each other, are considered. The vector $\mathbf{R}_i^{soc}$ points from the centre of human i to the fictitious contact point of the social force, see Fig. 3.

Analogous to the motive force, the first term on the right hand side of Eq. 2, a motive torque is defined as

$$M_i^{\tau} = \frac{I_i^z}{\tau_i^z} \left((\varphi_i(t) - \varphi_i^0)\omega_i^0 - \omega(t) \right) = \frac{I_i^z}{\tau_i^z} \left(\tilde{\omega}_i^0 - \omega(t) \right) \ , \tag{9}$$

where ω_i^0 is the maximum target angular speed of a turning human, $\omega(t)$ the current angular velocity, $\varphi_i(t)$ the current body angle, and φ_i^0 is the target angle, i.e., where the vector $\mathbf{v}_i^0$ is pointing. The target angular

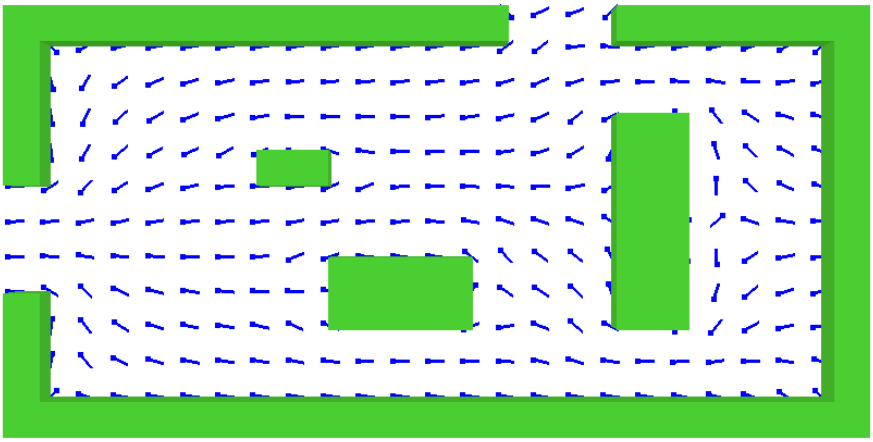

Figure 4: A 2D flow field used to guide humans to the exit doors. In this case, only the left exit has an "outflow" boundary condition, i.e., this fictitious human flow field is used to find the left exit only. The main evacuation mesh should also have an "outflow" boundary at the top exit.

speed, $\tilde{\omega}_i^0$, defined in Eq. 9 is larger when the body angle differs much from the desired movement direction. Langston *et al.* [10] used a different formula for the motive torque, which had a form of a spring force. During this work, it was noticed that a force like that will make humans to rotate around their axis like harmonic oscillators and, thus, some angular velocity dependent torque should be used.

In FDS+Evac method, humans are guided to exit doors by the preferred walking direction vector field, $\mathbf{v}_i^0$, and this field is obtained using the flow solver of the FDS. This vector field is obtained as an approximate solution to a potential flow problem of a two-dimensional incompressible fluid to the given boundary conditions, where all walls are inert and the chosen exit door acts as a fan, which extracts fluid out of the domain. This method, or rather a trick, produces a nice directional field for egress towards the chosen exit door, see Fig. 4. A field of this kind will always guide humans to the chosen exit door. This route will not be the shortest one, but usually it is quite close to it. This field will guide more humans to the wider escape routes than on the narrower ones due to the fact that the field is a solution to an incompressible flow. Note, that in the present version of FDS+Evac, escaping agents have a rule for the exit door selection. Thus, the above sentence applies when there are many routes to the chosen exit door or when the user is allowing more than one exit door per a flow field. The analogy to an incompressible fluid flow is not a bad starting point to find the movement directions of large human crowds. For example, when humans are leaving a large sports or entertainment event, they usually just follow the human flow to the outside of the building without much control on the process.

The human movement method presented in Eqs. 1–9 has many parameters. Some of these parameters are related to physical dimensions of humans, like m_i and I_i^z, but many parameters are related to the chosen model. Some of these parameters are chosen to be the same as found in the literature [7, 10] and some are estimated from test calculations. The parameters of the social force were chosen such that the specific human flows through doors and corridors were appropriate. The parameters for the three circle representation of human contact forces and the rotational degrees of freedom were selected mainly by trial and error in order to obtain reasonably realistic human movement. Monte Carlo simulations were done to see, which are the most important model parameters and further analysis was focused on those parameters.

The first choice for the social force parameters of human-human interaction was $A_i = 2000$ N, $B_i = 0.04$ m, and $\lambda_i = 0.5$. For the human–wall interaction values $A_w = 2000$ N, $B_w = 0.08$ m, and $\lambda_w = 0.2$ were used. It was noticed that these values are not good for congested situations when three circles are used

to describe a human body. These parameters were modified such that the interaction strength parameter A was made velocity dependent, $A(v_i) = 2000\,\mathrm{Max}(0.5, v_i/v_i^0)$ N.

For the contact force parameters, values $k = 12\times10^4$ kg m^{-2}, $\kappa = 4\times10^4$ kg s^{-1}m^{-1}, and $c_d = 500$ kg s^{-1} are used both for the human–human and for the human–wall interactions. The mass of a default male is $m_i = 80$ kg and his moment of inertia was chosen to be $I_i^z = 4.0$ kg m^2. For other humans, the mass and the moment of inertia are obtained by scaling. For the relaxation angular time parameter, τ_z, a value of 0.2 s is used. The angular velocity parameter ω_i^0 has a value of 4π s^{-1}, i.e., two rounds per second, in FDS+Evac.

In principle, all the above parameters may be dependent on the person in question. But in FDS+Evac, only the body sizes, walking velocities, and the motive force parameter τ_i are personalised by choosing them from a random distribution. A uniform distribution ranging from 0.8 s to 1.2 s is used for τ_i and the used uniform distributions for the body dimensions and for the walking speeds are shown in Table 1.

3.3 Fire and Human Interaction

By using FDS as the platform of the evacuation calculation we have direct and easy access to all local fire related properties, like gas temperature, smoke and gas densities, and radiation levels. Fire influences evacuation conditions; it may incapacitate humans and in extreme cases block major exit routes. On the other hand, humans may influence the fire by opening doors or actuating various fire protection devices. For now, the effect of smoke on the movement speeds of humans and the toxic influence of the smoke are implemented in movement algorithm of FDS+Evac. The exit selection algorithm of the agents uses smoke density to calculate the visibility of the exit doors.

Smoke reduces the walking speed of humans due to the reduced visibility, its irritating and asphyxiant effects. Recently, Frantzich and Nilsson [17] made experiments on the effect of smoke concentration on the walking speeds of humans. They used larger smoke concentrations than Jin [18] and they fitted the following formula to the experimental values

$$v_i^0(K_s) = \frac{v_i^0}{\alpha}(\alpha + \beta K_s)\ , \tag{10}$$

where K_s is the extinction coefficient ($[K_s]$=m^{-1}) and the values of the coefficients α and β are 0.706 m s^{-1} and -0.057 m^{2}s^{-1}, respectively. The standard deviations are reported to be $\sigma_\alpha = 0.069$ m s^{-1} and $\sigma_\beta = 0.015$ m^{2}s^{-1}, but only the mean values are used in FDS+Evac, i.e., there is no variation between the agents.

The toxic effects of gaseous fire products are treated by using Purser's Fractional Effective Dose (FED) concept [16]. The present version of FDS+Evac uses only the concentrations of the narcotic gases CO, CO_2, and O_2 to calculate the FED value

$$\mathrm{FED_{tot}} = \mathrm{FED_{CO}} \times \mathrm{HV_{CO_2}} + \mathrm{FED_{O_2}} \tag{11}$$

Note, that the above equation does not contain the effect of HCN, which is also narcotic, and the effect of CO_2 is only due to the hyperventilation, i.e., it is assumed that the CO_2 is such low that it does not have narcotic effects. Carbon dioxide does not have toxic effects at consentrations of up to 5 percent but it stimulates breathing which increases the rate at which the other fire products are taken up. The fraction of an incapacitating dose of CO is calculated as

$$\mathrm{FED_{CO}} = 4.607\cdot10^{-7}(C_{\mathrm{CO}})^{1.036}\ t\ , \tag{12}$$

where t is time in seconds and C_{CO} is the CO concentration (ppm). The fraction of an incapacitating dose of O_2 is calculated as

$$\mathrm{FED_{O_2}} = \frac{t}{60\exp\left[8.13 - 0.54(20.9 - C_{\mathrm{O_2}})\right]}\ , \tag{13}$$

Table 2: Preference order used in the exit selection algorithm. The last two rows have no preference. This is because the evacuees are unaware of the exits that are unfamiliar and invisible and, thus, can not select these exits.

preference	visible	familiar	disturbing conditions
1	yes	yes	no
2	no	yes	no
3	yes	no	no
4	yes	yes	yes
5	no	yes	yes
6	yes	no	yes
No preference	no	no	no
No preference	no	no	yes

where t is time in seconds and C_{O_2} is the O_2 concentration (percent). The carbondioxide induced hyperventilation factor is calculated as

$$\mathrm{HV}_{\mathrm{CO}_2} = \frac{\exp(0.1930\, C_{\mathrm{CO}_2} + 2.0004)}{7.1}\,, \tag{14}$$

where C_{CO_2} is the CO_2 concentration (percent).

Human is considered to be incapacitated when the FED value exceeds unity. An incapacitated human is modelled as an agent, who does not experience any social forces from the other humans and whose target movement speed, v_i^0, is set to zero. The size of an incapacitated human is not changed, i.e., he/she remains on his/her feet. This is a very crude model and it needs to be modified in later versions of FDS+Evac.

3.4 Exit Selection

Game theoretic reaction functions and best response dynamics are applied to model the exit route selection of evacuees. In the model, each evacuee observes the locations and actions of the other evacuees and selects the exit through which the evacuation is estimated to be the fastest. Thus, the exit selection is modelled as an optimisation problem, where each evacuee tries to select the exit that minimises the evacuation time. The estimated evacuation time consists of the estimated time of walking and the estimated time of queueing. The walking time is estimated by dividing the distance to the exit by the walking speed. The estimated time of queueing is a function of the actions and locations of the other evacuees. It is also assumed that people change their course of action only if there is an alternative that is clearly better than the current choice. This behaviour is taken into account by subtracting a parameter from the estimated evacuation time of the exit currently chosen.

Apart from the locations of exits and the actions of other people, there are also other factors that influence the evacuees' decision making. These factors are the conditions related to the fire, the evacuees' familiarity with the exits and the visibility of the exits. The effect of these factors is taken into account by adding constraints to the evacuation time minimisation problem. According to the three factors mentioned, the exits are divided to seven groups so that each exits will belong to one group. The groups are given an order of preference.

The familiarity of each exit for each agent can be determined by user in the input-file of FDS+Evac. It is also possible to give a probability for the familiarity of an exit, and FDS+Evac will randomly set the familiarity of the exit. FDS+Evac determines the visibility of an exit to an agent by taking into account the

blocking effect of smoke and obstacles. The possible blocking effect of other agents is not considered in the current version of the programme. The existence of disturbing conditions is estimated from the fire-related data of FDS on the visible part of the route to the exit. By disturbing conditions we mean conditions, like temperature and smoke, that disturb an evacuee but are not lethal. If there are lethal conditions on an exit route, the exit has no preference.

The exit selection algorithm consists of the above described two phases. First the exits are divided to the preference groups according to Table 2. Then, an exit is selected from the most preferred nonempty preference group by minimising the estimated evacuation time.

According to socio-psychological literature [12, 19], the familiarity of exit routes is an essential factor influencing decision making. This is because the unknown factors related to unknown routes are considered to increase the threat. As a result, evacuees prefer familiar exit routes even if there are faster unfamiliar routes available. For this reason, emergency exits are used rarely in evacuations and fire drills.

3.5 Groups

According to socio-psychological literature, a crowd consists of small groups, like families, that tend to act together [12]. This behaviour should be taken into account when building evacuation models. A method for modelling this grouping behaviour with the equations of Helbing was developed. In the model, the actions of a group are divided into two stages:

1. In the gathering stage the group members walk towards each other to gather the group.

2. In the egress stage the group moves together along the selected exit route.

These two stages are modelled by altering the preferred walking direction field of Helbing's equation of motion. In the gathering stage the pedestrians are trying to move towards the centre of the group. When the distances from the centre to each pedestrian are under a threshold value, the group is considered to be complete. When a group is complete, it starts to move towards an exit. This means that each group member is set to follow the same flow field. While moving towards an exit, the group members also try to keep the group together. This is modelled by adjusting the walking speeds and by adding an additional force that points to the centre of the group. This force is called as the group force. The magnitude of the group force describes how eagerly the group members try to keep the group together. It can be given different values for different kinds of groups. For example, a group consisting of a mother and a child should have a larger group force than a group of work mates.

The group-model is not yet available in FDS5, but it will be added to later versions of the program. The model has been programmed to a test-version and the results are promising, but quantitative effects of the model are yet to be analysed. The results of these analyses will be presented in a separate paper.

3.6 Numerical Method

The translational and rotational equations of motion are solved using a modified velocity-Verlet algorithm, where the translational motive force part is solved using a self-consistent dissipative velocity-Verlet algorithm [22] and the other parts are solved using the standard velocity-Verlet algorithm, which can be found in any basic textbooks on molecular dynamics simulations. The time step used in the algortihm is adjusted during the simulations by the maximum forces excerted on humans. The time step varies between 0.0xx1 and 0.0xxx1 seconds.

Exit door algorithm: The estimated evacuation time is approximated in the present version of FDS+Evac simply by dividing the distance to the door by the unimpeded walking velocity of the person. The distance to a door is calculated along a bee line both for the visible and non-visible doors. The distance should

be calculated along the exit path and also an estimated queueing time at the door should be added to the estimated evacuation time, but this is not yet implemented in the model.

The smoke density calculated by the FDS5 fire simulation can be used to detect a fire. By default, smoke density is not used for detection. User gives as inputs a detection time (distribution) and a reaction time (distribution) for the evacuating humans. If smoke is used to detect fire then user should give the detection threshold concentration (mg/m^3). A human detects a fire when the smoke concentration reaches its threshold value at the position of the human or if the user given detection time has been reached.

The smoke or toxic gas concentrations affect the exit door selection algorithm. By default, toxic gas concentrations are used (CO, CO2, O2: FED effect): door is 'no-smoke' if FED (time=dist/v0) less than 0.000001. A door is usable (and visible) as long as FED less than unity. If smoke concentration is used then user gives the threshold visibility value for a door to be 'no-smoke'. A door is usable, i.e., visible, as long as visibility is 0.5*distance to the door. (Visibility = 3/extinction coeff.) If there is no line-of-sight to the door, local concentrations at the human position are used and the distance to the door is calculated along a bee line (this is a crude approximation but fast to compute).

4 Testing and Verification

4.1 Introduction

An archive of the verification tests of FDS+Evac are on the FDS+Evac web pages. These verification tests include the ones suggested in the IMO Interim paper [21] and some other component and numerical tests. This manual contains only a short summary of these test and it might not be up to date, so more interested reader should visit the web pages to get the most recent information.

4.2 Component Testing

IMO and other component tests:

1. IMO 1: Maintaining set walking speed in corridor
2. IMO 2: Maintaining set walking speed up staircase
3. IMO 3: Maintaining set walking speed down staircase
4. IMO 4: Exit flor rate
5. IMO 5: Response time
6. IMO 6: Rounding corners
7. IMO 7: Assignment of population demographics parameters
8. Smoke vs momement speed tests: 1, 4, 7 1/m extinction coeff
9. FED tests: CO, CO+CO2, O2

For the functional verification required by IMO a good technical documentation should be enough. The manual should set out in a comprehensible manner the complete range of model capabilities and inherent assumptions and give a guide to the correct use of the capabilities.

4.3 Qualitative Verification

IMO and other qualitative tests:

1. IMO 8: Counterflow – two rooms connected via a corridor
2. IMO 9: Exit flow: cowd dissipation from a large public room
3. IMO 10: Exit route allocation
4. IMO 11: Staircase

The tests suggested by IMO do not include any quantitative verification, because IMO sees that "At this stage of development there is insufficient reliable experimental data to allow a through quantitative verification of egress models. Until such data becomes available the first three components of the verification process (component testing, functional verification, qualitative verification) are considered sufficient."

4.4 Numerical Tests

1. CORR and walking speed: CORR and EVSS stairs with many different ways:

5 Model Sensitivity

5.1 Introduction

This section concentrates on the effects of different input parameters on the outputs. Especially the flows through doors, corridors and stairs are examined, because these are usually the main bottlenecs of an evacuation of a building. This section does not address the point if the chosen algorithms, numerical methods, etc. are appropriate for the evacuation simulation or not. Only the sensivity of the chosen algorithms and numerical methods are examined and reported.

5.2 Grid Sensitivity

In principle, the algorithm described in Sec. 3 does not have any underlaying grid. It is continuous in time and place. But the implementation of the method in FDS+Evac introduces computational grids. These grids are used to define the geometry of the calculation. The most obvious grid sensivity issue is that the resolution for the obstructions, like doors, stairs, etc., is the grid resolution. The other, subtler effect is the way how the grid resolution changes the evacuation flow fields used to guide humans to the exit doors. In some cases, a finer grid does always mean a better guiding field for humans. If the evacuation grid resolution is much less than the half of the body dimension then one may find some difficulties to obtain nice evacuation flow fields, see the IMO test case 10 in **??**.

The FDS fire calculation grid has effects on the evacuation calculation via the smoke, toxic gas, temperature, and radiation level calculation. How accurate are the predictions of FDS for the fire products will, of course, depend on the FDS grid resolution. See the FDS Technical Guide for the effects of the grid resolution on the FDS fire calculation. The evacuation calculation interpolates the fire calculation results to the 2D evacuation grids and the evacuation grid resolution will have an effect on the spatial accuracy of this fire related information, but usually grid sizes are equal or less than the dimensions of a human body and, thus, the accuracy of the fire information in the evacuation grids is fine enough.

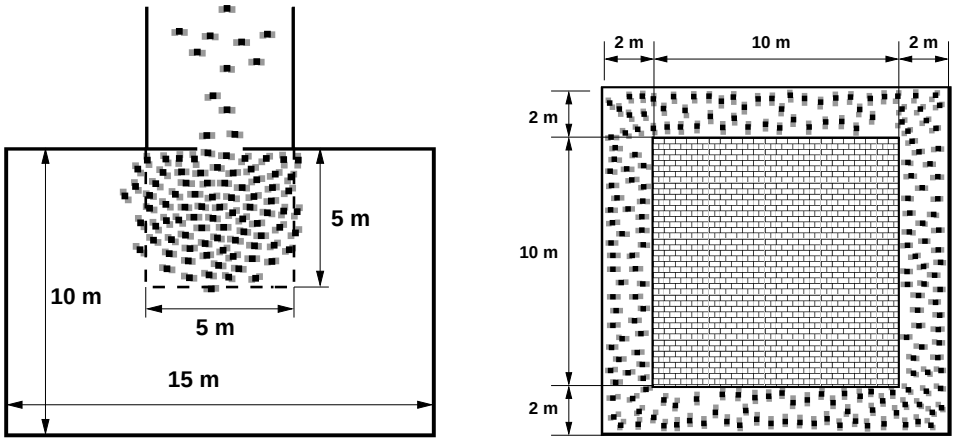

Figure 5: Test geometries used to calculate the specific flows through doors and corridors.

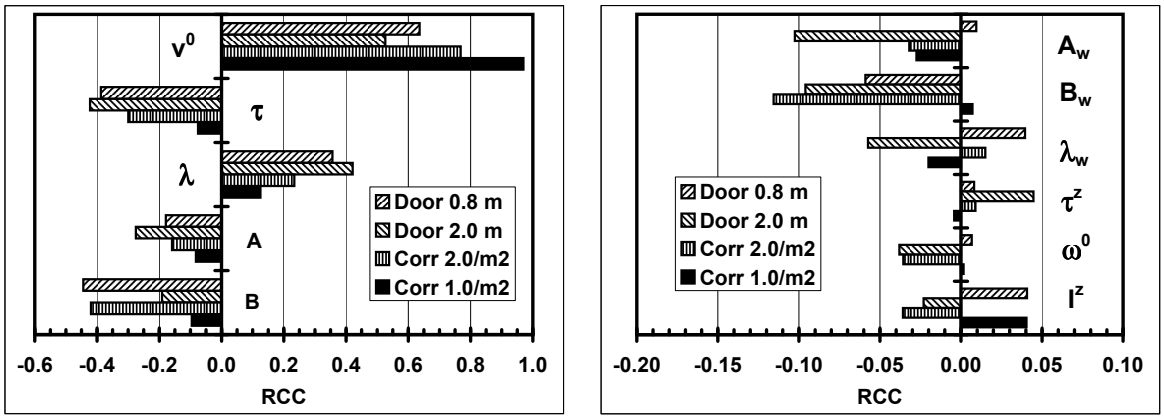

Figure 6: Rank correlation coefficients (RCC) for specific flows through doors and corridors. Widths 0.8 m and 2.0 m were used for doors and human densities 1.0 m^{-2} and 2.0 m^{-2} were used for corridors.

5.3 Human Parameter Sensitivity

The human movement algorithm of FDS+Evac has many parameters. Some of these are related to the physical description of humans, like the body size, the mass, the walking speed, and the moment of inertia. The others are the parameters of the chosen movement model, τ, τ^z, ω^0, the parameters of the social force, A, B, λ, and the parameters of the contact force, k, κ, c_d. To test the relative importance of these parameters, Monte Carlo simulations were performed to find the parameters which have the greatest effect on human flows. Two different geometries were used in the simulations, see Fig. 5. One of the geometries was used to study the flow of humans through a narrow door and through a wide door and the other geometry was used to study human flows in a corridor using densities 1.0 and 2.0 persons per square metre. There were 100 humans randomly located at the 5×5 m^2 square in the door flow calculations. Corridor flow calculations had 96 or 192 humans inside the corridor depending on the density. Thousand egress simulation with different random initial human properties were performed for each of these four different cases. In total eleven model parameters, A_i, B_i, λ_i, v_i^0, τ_i, A_w, B_w, λ_w, ω_i^0, τ^z, and I_i^z, whose values were varied ± 20 % using uniform distributions. The monitored output quantity was the specific human flow in all cases and the Spearman's rank correlation coefficients (RCC) were calculated for these four cases and they are shown in Fig. 6.

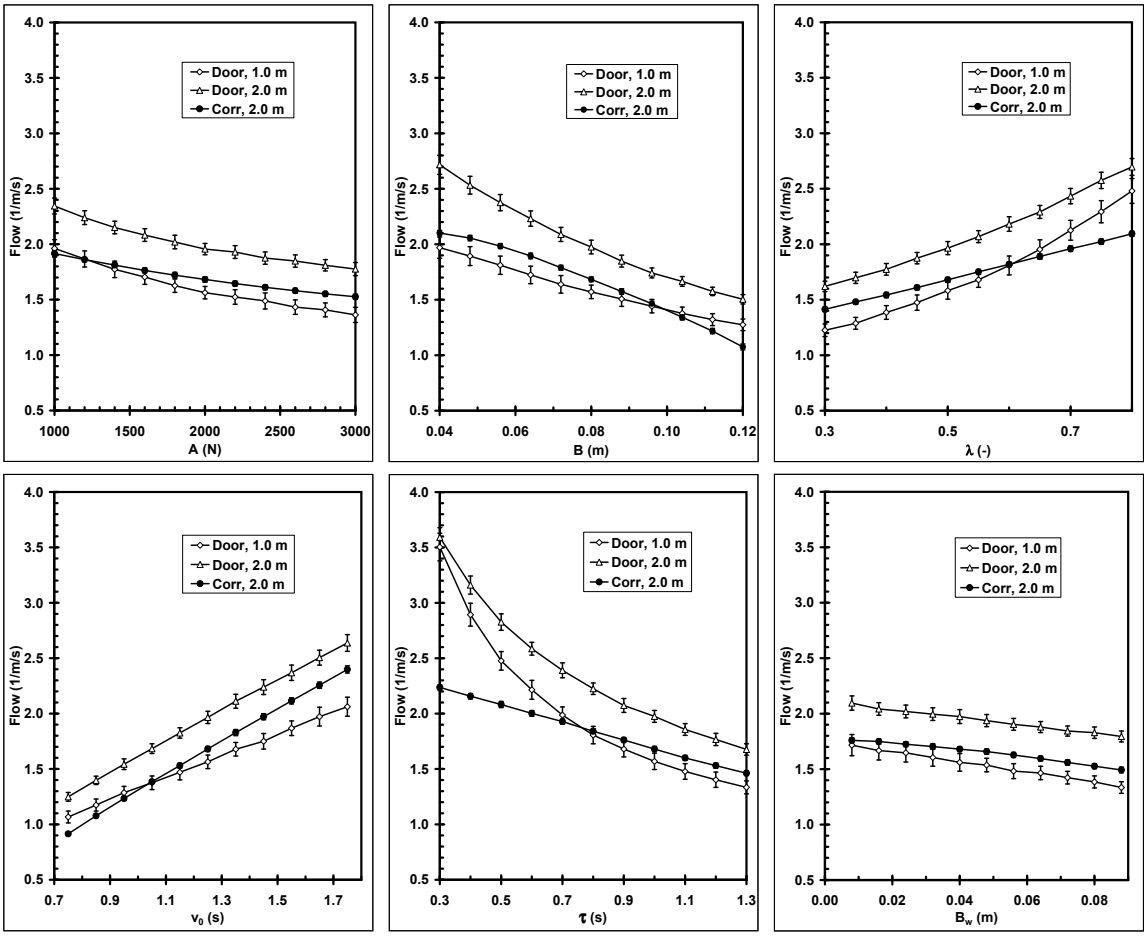

Figure 7: Effects of different model parameters, A_i, B_i, λ_i, v^0, τ_i, and B_w on the specific flows through doors and corridors. The corridor has 2.0 m^2 human density and two doors widths, 1.0 m and 2.0 m, are used.

It is seen from Fig. 6 that the parameters A_i, B_i, λ_i, v_i^0, τ_i, and B_w have the largest impact on the specific flows through doors and corridors. Thus, further simulations were done to quantify these effects. Each of these six parameters were varied separately and 100 simulations were done for each discretely chosen value of the parameters. Two different door widths, 1.0 m and 2.0 m, were chosen to represent a narrow and a wide door. Corridor flow was calculated using a density of 2.0 persons per square metre, because it is known that around this density the specific flow has its maximum value. The results of these, in total almost 20000 simulations, are shown in Fig. 7, where the markers represent the average of 100 simulations and standard deviation is shown as error bars. Note that in FDS+Evac the initial properties and positions of humans are not deterministic, because the humans are randomly positioned, the parameters R_d, v^0, and τ_i, are sampled from a random distribution and there are small random forces in Eqs. 1 and 5. Increasing the values of A_i and B_i increases the social force which tries to keep humans apart from each other and, thus, the specific flow for door geometry will decrease. The corridor case has a constant human density. Thus, these two parameters can not have an effect through the density. Larger social force, i.e., larger A and/or B, will make a forward walking person to reduce his/her speed in order not to step on someone's heels, when the anisotropy parameter, λ_i, is less than unity. Increasing the walking velocity will, of course, increase the specific flow. Decreasing τ_i, i.e., increasing the motive force to go forward, increases specific flows quite

rapidly for the door geometry. This effect is not as pronounced in the corridor case, because there is no free space in front of humans to accelerate and also the humans are already moving with some velocity whereas they are almost standing and waiting their turn in front of the door. The anisotropy parameter of the social force, λ_i, controls how eager humans are to push those who are in front of them. When λ_i is large then humans are 'pushy'. The effect of the wall force parameter B_w is to modify the effective width of doors and corridors, thus, increasing its value will make the effective width smaller and this will decrease human flows slightly.

5.4 Summary

One should be very careful when constructing the geometry, where humans are moving. One should use Smokeview to see the human flow fields before making a full evacuation simulation.

The effect of the parameters in the human movement algorithm, Eqs. 1–9 are understood well and user should usually not use any other than the pre-defined person types in FDS+Evac. There are different sets of person types suited to different situations: Standard egress, UK regulations, IMO requirements, etc.

6 Model Validation and Verification

6.1 Introduction

6.2 Comparisons with Test Data

Case 1: RI Nightclub: ToDo

Case 2: Theatre at Tampere, Finland: ToDo

Case 3: Stairs in an office building in Helsinki.

6.3 Comparisons with Engineering Correlations

See Section 5.3.

Stair flows, door flows, corridor flows. Here also comparison with other evacuation models for these simple test geometries.

6.4 Comparisons with Other Evacuation Models

See the FDS+Evac web page, where the following test cases have been reported.

Sports hall (Eerikkilä)

Open floor office (Banque Populaire)

Assembly space

7 Running FDS+Evac

Running FDS+Evac is similar to running FDS, i.e., relatively simple. All of the parameters that describe a given fire and egress scenario are typed into a text file that will be referred to as the "fds" or the "input" file. In this document, the data file will be designated as **CHID.fds**. In practice, the user chooses the ID string "CHID" so that all of the files associated with a given calculation all have a common prefix.

In Section 11, an example input file will be presented. Several other example files exists at the FDS+Evac web site `http://www.vtt.fi/fdsevac`. It is suggested that a new user start with an existing input file, run it as is, and then make the appropriate changes to the input file for the desired scenario. By running a sample case, the user will become familiar with the procedure, learn how to examine the results, and ensure that his/her computer is up to the task before embarking on learning how to create new input files.

The FDS+Evac executable is a single CPU executable of the FDS, fds5.exe). Assuming that an input file called **CHID.fds** exists in some directory, the user must run the program in a DOS command shell as follows:
Open up a Command Prompt window, and change directories to where the input file for the case is, then run the code by typing

```
fds5.exe  CHID.fds
```

to begin a run, which will output some text on the Command Prompt window. If the user wants to save the text output going on the Command Prompt window, she/he should type

```
fds5.exe  CHID.fds 2&>1 > CHID.err
```

to begin a run.

7.1 Updating an Existing FDS Input File to a FDS+Evac Input File

- Make a FDS fire input file for your project and do the fire/smoke spread calculations using the single CPU version of the FDS executable. Note, that the present version of the evacuation module demands that the fire part can be run using the serial version of FDS. If the memory requirements of your fire calculation demand the use of the MPI version of FDS then you can not couple the evacuation calculation with the fire calculation, i.e., you can not use smoke and gas consentrations in the evacuation calculation. If you are going to do run FDS+Evac only in the "evacuation trial mode" then the fire grids are not used and the memory requirements might not be as large, so you might be able to run just the evacuation calculation.

- Save the fire input file to some other name (and change also the `CHID` on the `HEAD` namelist group).

- Put a keyword `EVACUATION=.FALSE.` to every `HOLE` line, which you fire input has. Make a copy of each `HOLE` line which you want also to appear in the evacuation geometry and change `EVACUATION` value to `.TRUE.` This may sound like a nuisance, but the way how FDS parses the input file demand that.

- Add a line `&SURF ID='OUTFLOW', VEL=+0.000001, TAU_V=0.1 /` to your input file.

- Define meshes for the evacuation. Each floor should have its own mesh. The z co-ordinate for these meshes should be at a level, where the most obstacles for the movement are, usually about one meter above the floor. See Fig. 8 and Sec. 8.1.

- Put `T=0.0` on the `TIME` namelist group, comment out the fire meshes, i.e., remove ampersands at the beginnings of the fire mesh lines, and run FDS+Evac. Use Smokeview to see, if the 2D geometry is looking right. You can play around with the $z_{\min}$ and $z_{\max}$ to take the evacuation layout at different heights.

- Define additional obstacles with `EVACUATION=.TRUE.`, where you do not want humans walking. No need to define `SURF_ID` for evacuation obstacles, because the default for these is `INERT`.

- Make additional holes with `EVACUATION=.TRUE.`, where they are needed. Usually these are needed at exits or doors. See Fig. 2 and Sec. 1.2.

- Run FDS+Evac (`T=0.0`) and see if the 2D geometry is looking correct. If not, correct it by adding more `OBST`s and `HOLE`s.

- Define evacuation flow field vents (`EVACUATION=.TRUE., SURF_ID='OUTFLOW'`) that suck fluid out of the evacuation meshes at the places where you want humans to go. These vents should be placed at the doors and exits. Note, that in FDS5 vents should be defined on solid surfaces. If you are using multiple human flow fields on a floor then you should specify the `MESH_ID` on the `VENT` lines. This specifies the evacuation mesh, where this vent is put. Same applies to holes and obstacles as well, but usually one can use same obstacles and holes on each flow field. Remember to define slice output files at your evacuation mesh heights, e.g.,
  `&SLCF PBZ=x.x, QUANTITY='VELOCITY',VECTOR=.TRUE./`

- Remove `CHID_evac.eff` file if it exists. Run a short simulation, i.e., put `T=1.0`. Check the human flow fields by using Smokeview. Check also that your evacuation geometry looks fine. If not, add obstacles or holes to the evacuation calculation and remember to remove the `CHID_evac.eff` file. Repeat these steps as long as you are satisfied with the geometry. Note, that FDS+Evac tries to read the human flow fields from the disk if there exitst a `CHID_evac.eff` file. This file should be recalculated each time when you make changes to the geometry by changing objects like `OBST`, `VENT`, `HOLE`, and `MESH`.

- Define your person classes, the `PERS` namelist groups. These define the properties of the humans in the model. Also the detection and reaction time distributions are given here.

- Define your doors, exits, stairs, and entries, the `DOOR`, `EXIT`, `CORR`, and `ENTR` namelists. Activate meshes in Smokeview to see the actual positions of your obstacles in the evacuation meshes, which might be a little bit different than the values given in the input file due to the fact that FDS moves `OBST`s, `HOLE`s, and `VENT`s to match the mesh cell boundaries. See Sec. 1.2 and Fig. 2 how doors should be defined.

- Place the humans inside the building, the `EVAC` namelists. Use `EVHO` namelists if needed. Note, that humans should not be placed behind the exits or doors, but this is no problem, because exits and doors are usually defined on solid `OBST`s.

- Once again, run a short simulation. See, that your humans have correct initial positions. Edit the initialization file of Smokeview (smokeview.ini or CHID.ini) to make the squares that represent humans larger by changing the value of `PARTPOINTSIZE`. Note, that now you had the file `CHID_evac.eff` on your disk so this file was read in, i.e., the human flow fields were not recalculated and the calculation runs faster than before.

- Run a longer simulation and see that the humans are moving correctly, i.e., they are following correct flow fields and the exits, stairs, and doors are working correctly. Note that the reaction and detection time distributions given on the `PERS` lines should be shorter than the simulation time to see some human movement. (pre-evacuation time = detection time + reaction time)

- Do a full evacuation calculation and save the results, i.e., the CHID_evac.csv file. Repeat this step a dozen or so times. Note, that the results are not exactly similar, because humans have random properties and initial positions. These simulations correspond to a fire drill. After this, activate the fire meshes, i.e., put the ampersands back to the fire mesh lines, and do a full FDS+Evac simulation. Now the fire and evacuation simulations are done at the same time and a file `CHID_evac.fed` is written to hard disk. This file can be used to run many evacuation simulations per one fire simulation, i.e., no need to calculate the same fire for many times. Note, that the CHID_evac.eff file is (re)calculated always when there are active fire grids.

- If you are doing more than one evacuation calculation per one fire scenario (as you should) then save the CHID_evac.eff and CHID_evac.fed files after the previous step, where fire and evacuation calculations were done at the same time. Then comment the fire meshes out, i.e., the ampersands away once again, and rerun the case. Copy the results (CHID_evac.csv) to some other name and rerun once again, etc. For a given fire, you should run the evacuation part a couple of dozen times, because the FDS+Evac is not deternimistic model. After the runs, examine the results: calculate averages, variances, etc.

7.2 Getting Help, Error Statements, Bug Reports

- Send bug reports to: `Timo.Korhonen@vtt.fi`. The subject line should start with the characters `FDS+Evac Bug:`.

- Send help requests to: `Timo.Korhonen@vtt.fi`. The subject line should start with the characters `FDS+Evac Help:`.

- If the run stops early and the error message “ERROR: Initialize_Humans, Evac line #, Mesh #, i_human #” is printed on stderr then the initialization of humans failed, i.e., FDS+Evac was not able to put the humans on the areas specified in the input file. Check that you are not trying to put too many humans on a too small area. See the positions of those humans that FDS+Evac was able to generate by using Smokeview. Note, that in some runs with the exactly input file you might get the error message and in some other runs not. The reason for this is that FDS+Evac uses random numbers to generate the properties of humans and their initial positions.

8 Setting up the Input File for FDS+Evac

This section is a short manual to the FDS+Evac program. Read first the FDS manual, because here only those features and keywords are presented, which differ from the ordinary FDS fire input. The optional keywords are presented with a slanted typewriter font, like *KAPPA*, and the normal keywords with upright typewriter font, like XB. One can use the optional keywords to override the default values of different parameters.

Note, that the FDS+Evac is still under construction and so is this manual. See the example FDS+Evac calculations and read through the example input files on the FDS+Evac web page. These example input files contain many comment lines, which explain all the major features of the FDS+Evac input file format and how to do a FDS+Evac simulation. Some general notes on FDS+Evac and some special features and warnings are listed below:

- New meshes must be defined for the evacuation calculation part. These meshes are not related to the fire calculation meshes, i.e., their dx and dy may be different and the spatial extent of the meshes may also be different. Usually one defines one main evacuation mesh per one floor of the building, if the spaces on this floor are connected. If there are more than one evacuation zone on a given floor then different main evacuation meshes may be used for this floor.

- The evacuation input should be matched to the evacuation floor mesh definition. Check the actual locations of the obstacles using Smokeview. The evacuation related input, e.g., namelists DOOR, EXIT, ENTR, and EVAC, is not moved to the closest mesh points. For now, Smokeview does not show these evacuation related objects.

- In the evacuation meshes all obstacles are thick, i.e., they fill at least one mesh cell in each direction (x and y).

- The evacuation meshes are two dimensional, i.e., they should have IJK=N_x,N_y,1 on the MESH lines.

- The present version of FDS+Evac places the different evacuation objects to the different evacuation meshes according to their x, y, z co-ordinates by default. One object should belong only to one main evacuation mesh. It the position of the evacuation objects, like exits and doors, is ambiguous then a keyword MESH_ID should be given to specify the correct main evacuation mesh.

- There are many keywords, which might be given in the FDS+Evac input file and these are also read in, but the values are not used yet. This manual only explains keywords, which actually have some effect on the calculation. (If one looks the evac.f90 source code, one finds a quite many non-used keywords.)

- The positions of doors and exits are not checked, i.e., the user should give VENTs and OBSTs so that in the final FDS+Evac calculation geometry there is an evacuation VENT every EXIT and DOOR in the main evacuation meshes or otherwise humans can not enter these doors, because they feel repulsive forces exerted by the solid objects behind the doors.

- It is good idea to put an exit or a door a little bit inside a hole in the wall, see Fig. 2. This makes the door flow better, because then the door posts will exert forces on humans.

- Check your EVAC lines that you are not putting humans in areas, where humans should not be. Check also that humans can not go 'out of bounds', i.e., that there are no openings in the evacuation geometry where no door nor exit is defined.

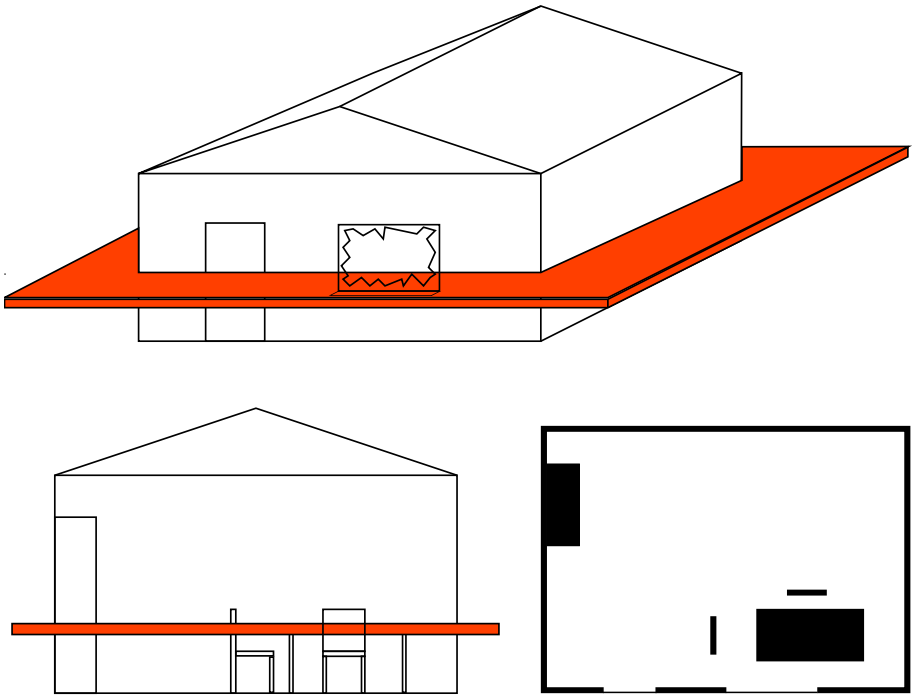

Figure 8: A 2D evacuation mesh.

- Check your EVAC lines that you are not trying to put too many humans on a too small area. Typical human diameter is somewhere between 0.5-0.6 m, so you can not put more than about four person per a square meter. If you are trying to populate the floor more densly, the program will stop after the initialization phase. Note, that the initial position of humans are random so different runs with the same input file may or may not stop for this reason, if the initial human density is close to the critical value. Use the Smokeview to see the initial positions of those humans who were positioned succesfully and see the output on stderr to see the position of the human, which could not be placed correctly at the initialization.

8.1 The Numerical Evacuation Meshes

The fire and evacuation meshes are separate ones. One can do only a fire calculation, only an evacuation calculation, or both at the same time. The calculation mode is chosen by activating the meshes or deactivating them, i.e., commenting the corresponding &MESH lines out.

Evacuation mesh lines have a keyword EVACUATION=.TRUE. on the &MESH line. The default is .FALSE., i.e., the fire meshes do not need the keyword EVACUATION. This is true also more generally, i.e., one can always run a fire simulation (using the fds5.exe executable) even if there exists evacuation input in the input file. The FDS5 fire calculation ignores all evacuation lines and keywords, if there is no active evacuation meshes.

Main evacuation meshes have also a keyword EVAC_HUMANS=.TRUE., which says that this mesh will contain humans. Usually, one main evacuation mesh represents a 'floor'. You need more main evacuation meshes on a floor if there exists separate parts of the floor, where the humans are not going to be using same exit routes. In principle, you could manage by one main mesh, but the calculation is faster if you define different meshes for the parts, which do not interact with each other.

All evacuation meshes should have a name, i.e., a keyword ID should be given on the &MESH line. The

name of the mesh should not be too long, max 26 characters. Of course, the names of different meshes can not be the same. The `ID` is used later to specify the mesh, where some additional evacuation objects are placed.

Evacuation meshes should have only one cell in the z direction, i.e., they are two-dimensional horizontal meshes, see Figure 8. Choose `IJK` and `XB` so that the dx and dy are nice round numbers, which will fit nicely to your geometry. You should give the positions of all evacuation objects as multiples of dx and dy. This is not obligatory but one makes less mistakes this way. FDS+Evac does not move the evacuation objects to the closest mesh points yet, this may change in later versions of FDS+Evac.

Evacuation meshes, which are only used to calculate (additional) human movement flow fields should have `EVAC_HUMANS=.FALSE.` or just no `EVAC_HUMANS` keyword at all. False is the default. Note, that these meshes should have exactly the same `IJK` and `XB` definitions as the corresponding main evacuation meshes. This is not checked by the program so the user should do the check.

8.2 The `TIME` Namelist Group

`EVAC_DT_FLOWFIELD` is the time step of the calculation of the evacuation flow fields. These fields are calculated before the fire and evacuation calculation, *i.e.*, simulation time has negative values. (Default is 0.01 s.)

`EVAC_DT_STEADY_STATE` is the maximum time step of the human movement algorithm, this should not be too large, should not be larger than 0.1 s. This parameter defines the minimum coupling frequency of different main evacuation meshes. Coupling is faster if the time step of the fire calculation is shorter. (Default is 0.05 s.)

8.3 The `SURF` Namelist Group

One should always define a new surface type for the evacuation calculation, which is used to construct the flow fields that guide the humans to the doors (or to other targets), see Figure 4 and the FDS+Evac Technical Reference Guide for details. The following line should be given on the input file:

```
&SURF ID = 'OUTFLOW', VEL = +0.000001, TAU_V=0.1 /
```

Note, that `VEL` should be a really small number, otherwise one might not get a nice 2D potential flow solution.

8.4 The `MISC` Namelist Group

`EVAC_SURF_DEFAULT` is the surface default for the evacuation meshes. The default is `INERT`. You could specify some other solid material for the default surface material, but FDS+Evac uses only the color information.

`EVAC_PRESSURE_ITERATIONS` is the number of Poisson solver iterations at each human flow field time step. If you human flow fields do not look nice, you might need to increase this. Too large number makes the human flow field calculation to take too much CPU time. (Default is 50.)

`EVAC_TIME_ITERATIONS` is the number of human flow field calculation time steps. One should have a nice converged human flow field, so some iterations are needed. Too large number means too long CPU time. (Default is 50.)

The flow fields, which are used to guide humans out of the building or to some other targets, are calculated before the actual fire and evacuation simulation, i.e., flow field calculation has $t < 0$. The product t_{flow} = *EVAC_TIME_ITERATIONS* $\times$ *EVAC_DT_FLOWFIELD* defines the duration of the evacuation flow field calculation. The fields should become 'steady-state' during this time. Note, that the ramp up time of the boundary conditions TAU_V=0.1 given on the &SURF ID='OUTFLOW' line should be well below the duration of the flow field calculation t_{flow}. Default t_{flow} is $50 \times 0.01\ \text{s} = 0.5\ \text{s}$.

8.5 The VENT Namelist Group

Because one needs to specify special VENTs for the evacuation calculation, the VENT namelist group has an additional logical item EVACUATION. If it is .TRUE. then this VENT is omitted in the fire calculation. The default value is .FALSE. The keyword MESH_ID should also be given, if the VENT is not needed in all evacuation flow field calculations on this floor. Note, that an evacuation VENT without MESH_ID is put on every evacuation flow field on this floor. This means that it is better always to have the item MESH_ID specified, if EVACUATION=.TRUE. is given. Note, that in FDS5 VENT must always be defined on a solid surface or on the outer boundary of the computational domain. Thus, the user may need to place additional evacuation OBSTs behind the VENTs used to generate the evacuation flow fields.

8.6 The OBST Namelist Group

One may need to specify special OBSTs for the evacuation calculation, which are not present in the fire calculation. Thus, the OBST namelist group has an additional logical item EVACUATION. If it is .TRUE. then this OBST is omitted in the fire calculation. If the evacuation flow fields need different obstacles for different human flow fields, then the item MESH_ID should be given for the evacuation obstacles. Usually these additional evacuation obstacles are introduced at places, where humans are not allowed to walk.

8.7 The HOLE Namelist Group

This is similar to the OBST namelist group. Only difference is that the HOLE lines of the fire calculation should have a keyword EVACUATION=.FALSE. set and these lines should be duplicated to the evacuation geometry having EVACUATION=.TRUE. set. If the evacuation flow fields need different holes for different fields, then the item MESH_ID should be given for the evacuation calculation holes. Holes are treated in the FDS input a little bit different than the obstacles, i.e., first all obstacles are read in and after this the holes are created. This is true for all meshes, so the evacuation meshes can mix holes and obstacles incorrectly, if there are no EVACUATION=.FALSE. on the fire calculation holes.

If you have an ordinary FDS5 input file and want to use this as a starting point of a FDS+Evac input file, you should add EVACUATION=.FALSE. keyword to every HOLE line, which you have in the FDS5 fire input. After this, you should duplicate these hole lines and change the kewyword EVACUATION value to .TRUE. if you want the same holes to appear correctly in the evacuation geometry.

8.8 The PERS Namelist Group

This namelist group is used to define human types. There are five default human types defined and they are 'Adult', 'Male', 'Female', 'Child', and 'Elderly', see Table 1 for their properties.

DEFAULT_PROPERTIES 'Adult', 'Male', 'Female', 'Child', or 'Elderly'. If not given, default values are used, see the end of Sec. 3.2. Note, that these values are overridden if they are explicitly given in the PERS namelist input line.

Properties like human diameter, walking speed, pre-evacuation time, and force constants are given here. Some of the values might be given as distributions. The distribution types are chosen by keywords *DIAMETER_DIST, VELOCITY_DIST, TAU_EVAC_DIST, DET_EVAC_DIST,* and PRE_EVAC_DIST, where the choices for the statistical distributions are listed on Table **??**. The most used ones are: 0) no distribution, X_MEAN is used; 1) uniform distribution, X_LOW and X_HIGH are used; 2) normal distribution, X_MEAN is the mean, X_PARA is the std.dev., X_LOW and X_HIGH are the cut offs, i.e., the values are within the interval (X_LOW,X_HIGH). If X_LOW is not given $\Rightarrow$ X_LOW=0.0. If X_HIGH is not given, then X_HIGH is a 'very large' number. Above, X refers to one of the strings *DIA*, *VEL*, *TAU*, *DET*, or PRE.

DET_MEAN,DET_PARA,DET_PARA2,DET_LOW,DET_HIGH detection time, parameters of the distribution.

PRE_MEAN,PRE_PARA,PRE_PARA2,PRE_LOW,PRE_HIGH reaction time, parameters of the distribution (is equal to pre-evacuation time if no detection time is given).

VEL_MEAN,VEL_PARA,VEL_PARA2,VEL_LOW,VEL_HIGH The target walking speed v_i^0, parameters of the distribution, see Eq. **??**

DIA_MEAN,DIA_PARA,DIA_PARA2,DIA_LOW,DIA_HIGH Diameter of human circle ($2R_d$), parameters of the distribution, see Table. 1 and Fig. 1.

TAU_MEAN,TAU_PARA,TAU_PARA2,TAU_LOW,TAU_HIGH relaxation time τ_i, parameters of the distribution, see Eq. **??**.

FCONST_A,FCONST_B,L_NON_SP Social force parameters A_i, B_i, λ_i, see Eq. **??**.

C_YOUNG,KAPPA Contact force parameters k and κ, see Eq. **??**.

D_TORSO_MEAN,D_SHOULDER_MEAN The mean diameters of the torso and shoulder circles, see Table. 1 and Fig. 1. The variation of the diameters is determined by the variation of the human circle ($2R_d$).

TAU_ROT relaxation time τ_i^z for the rotational equation of motion, see FDS+Evac Technical Reference Guide.

M_INERTIA moment of inertia I_i^z for the rotational equation of motion, see Eq. **??**.

FAC_A_WALL A_w for walls is FAC_A_WALL$*A_i$.

FAC_B_WALL B_w for walls is FAC_B_WALL$*B_i$.

LAMBDA_WALL λ_w for walls.

FC_DAMPING Damping coefficient c_d of the radial contact force, see Eq. **??**.

V_ANGULAR Maximum target angular speed of a human ω_i^0, see Eq. **??**.

NOISEME,NOISETH Gaussian noise, see Eqs. **??**. These parameters determine both the noise in the translational equation and the noise in the rotational equation.

COLOR_METHOD How humans are shown in Smokeview, see Table **??**. Default value is 0.

NOT_RANDOM If true, do not use random seed when generating the initial positions and characteristics of humans. Default is false.

NOTE: *FAC_x_WALL, LAMBDA_WALL, FC_DAMPING, V_ANGULAR, NOISExx, COLOR_METHOD, NOT_RANDOM* the last values read from PERS lines are used. So, it is nice practice to give these numbers just in one PERS group or have same numbers in every PERS group.
WARNING: Change only the reaction and detection time parameters, other parameters should have the default values and use the pre-defined person types, unless you know what you are doing.

8.9 The EVAC Namelist Group

Places humans in the evacuation meshes, i.e., the initial positions of the humans.

ID ID string of the group of humans.

XB where the humans are put, z should belong to a main evac mesh.

NUMBER_INITIAL_PERSONS how many persons are put in the area XB.

ANGLE By default the orientation of humans is random, but by giving angle (0–360) one can specify the orientation of persons. Angle 0 means that humans are facing towards $+x$.

QUANTITY Color of the squares in Smokeview. Note, that if a person is dead, it is colored as YELLOW.

PERS_ID From which person class the properties are generated (randomly). If no PERS_ID is given, then the default values are used.

FLOW_FIELD_ID Flow field in the 'room/floor', which this person is initially following, i.e., specifies to which door a person tries to go if no known nor visible door is available.

KNOWN_DOOR_NAMES The ID strings of the known exit doors.

KNOWN_DOOR_PROBS The probabilities that the exit doors are known. At the initialization phase the known doors for persons are drawn using these probabilities. Default values are equal to ones.

EVAC_MESH If there are overlapping main evacuation meshes then this parameter could be used to specify the mesh where this EVAC line is applied.

NOTE: If no PERS_ID is given on EVAC lines, then the default values are used for the properties of persons. These default values are given inside the code, and they might be changing during the development of the code. So, one should not use the default values.

8.10 The EVHO Namelist Group

ID ID string.

XB where the humans are not put, z should belong to a main evac mesh.

PERS_ID This hole apply just for this person type, i.e., has effect only on those EVAC lines, where *PERS_ID* matches.

EVAC_ID This hole apply just for on that EVAC line. If both *PERS_ID* and *EVAC_ID* are given, they are treated using the logical operator OR.

EVAC_MESH If there are overlapping main evacuation meshes then this parameter could be used to specify the mesh where this EVHO line is applied.

8.11 The EXIT Namelist Group

Defines an exit. Note, that an 'outflow' vent is not automatically created, so the user should give a separate VENT line. Exits might be used just to count humans, then the keyword *COUNT_ONLY=.TRUE.* is used and, thus, these can be placed anywhere inside the building. Humans, which move through an exit (*COUNT_ONLY=.FALSE.*), are removed from the calculation, i.e., they are supposed to be gone outside of the building and be safe.

ID ID string of the exit. One can refer to this exit by its name.

XB Co-ordinates, should be a line in the (x, y) plane, the z should belong to a main evacuation mesh.

IOR Direction of the door, e.g., +1 humans are going $+x$ direction -2 humans are going $-y$ direction (direction means: room $\Rightarrow$ exit $\Rightarrow$ outside of the building)

COUNT_ONLY If true, humans are not removed, they are just counted (default is false). The CHID_evac.csv file has a column for each EXIT regardless if *COUNT_ONLY* is true or false.

VENT_FFIELD The ID string of the evacuation flow field behind this exit door. The humans are guided to this exit door by the specified flow field.

FLOW_FIELD_ID Used, if this exit is a target for some other evacuation element and there are no known doors nor visible ones available. If *FLOW_FIELD_ID* is not given, then the main evacuation mesh flow field is used. WARNING: It is better to use a door or an entry instead of an exit if it is a target of some other evacuation element.

XYZ Co-ordinates, which are used in the exit door selection algorithm to decide if the exit is visible or not. Default is the mid-point of XB.

EVAC_MESH If there are overlapping main evacuation meshes then this parameter could be used to specify the mesh where this EXIT line is applied.

8.12 The ENTR Namelist Group

Defines an entry. An entry can enter humans to the calculation at a constant frequency. An entry with frequency zero can just be used as an end point of a corridor (or some door). This case corresponds to a one way door, i.e., humans can only come out from this 'door'.

ID ID string of the entry. One can refer to this entry by its name.

IOR direction of the entry, e.g., +1 humans are entering towards $+x$ direction -2 humans are entering towards $-y$ direction (direction means: somewhere $\Rightarrow$ entry $\Rightarrow$ room)

MAX_FLOW persons per second (actual flow may be smaller, if the area in front of the entry is crowded)

FLOW_FIELD_ID Flow field in the 'room/floor', which this person is following, i.e., specifies to which door a person tries to go if no known nor visible doors are available. If not given, the flow field of the main evacuation mesh is used.

KNOWN_DOOR_NAMES The ID strings of the known exit doors. This only apply to persons that are generated at this entry by the MAX_FLOW, i.e., it does not apply to those persons who are transfered to this entry from somewhere else.

KNOWN_DOOR_PROBS The probabilities that the exit doors are known. The known doors for the persons generated by this entry are drawn using these probabilities. Default values are equal to ones.

XB coordinates, should be a line in the (x, y) plane, the z should be 'main evac mesh' z coordinates.

QUANTITY color of the squares in Smokeview of the humans which are entered at a specific flow rate. If the humans are coming to this entry form some other node, then their original color is used instead of QUANTITY. This is used if the COLOR_METHOD=0 is specified on (some) PERS line.

PERS_ID the properties of humans are generated using these parameters, if they are not coming to this entry form some other node, i.e., they are 'new' humans. If not given, default values are used.

EVAC_MESH If there are overlapping main evacuation meshes then this parameter could be used to specify the mesh where this ENTR line is applied.

8.13 The DOOR Namelist Group

Defines a door. Similar to EXIT, but the humans are not removed from the calculation. The humans are put to some other part of the calculation (e.g., to a stairs, to a different 'room' etc.)

ID ID string of the door. One can refer to this door by its name.

XB coordinates, should be a line in the (x, y) plane, the z should belong to a main evacuation mesh.

IOR direction of the door, e.g., +1 humans are going $+x$ direction -2 humans are going $-y$ direction (direction means: room $\Rightarrow$ door $\Rightarrow$ some other place)

VENT_FFIELD The ID string of the evacuation flow field behind this exit door. The humans are guided to this exit door by the specified flow field.

FLOW_FIELD_ID Used, if this door is a target for some other evacuation element and there are no known doors nor visible ones available. If no FLOW_FIELD_ID is given, then the main evacuation mesh flow field of this floor is used.

XYZ Co-ordinates, which are used in the exit door selection algorithm to decide if the door is visible or not. Default is the mid-point of XB.

KEEP_XY saves the information on the position of the person relative to the width of the door, i.e., if the target of this door is DOOR or ENTR then human is placed according to this information.

TO_NODE Where humans are going, when going inside this door. TO_NODE can be DOOR, EXIT, CORR, or ENTR.

EVAC_MESH If there are overlapping main evacuation meshes then this parameter could be used to specify the mesh where this DOOR line is applied.

8.14 The CORR Namelist Group

Defines stairs (or a horizontal corridor). One uses these to move humans from one floor to the next one. The corridor (actually stairs) model is a really simple one. One gives the length of the stairs and reduces the movement speed. One also gives the maximum number of persons inside the corridor. For now there is no relation between the density and the movement speed (or human flow) inside the corridor.

ID ID string of the corridor. One can refer to this CORR by its name.

MAX_HUMANS_INSIDE how many humans fit inside the corridor.

XB, XB1, XB2 Used to specify the points, where the smoke and FED data is taken for this corridor/stair. If only one value is used for the corridor/stair, give XB. If the values at the beginning and at the end of the corridor/stair is used, give both XB1 and XB2, respectively.

EFF_LENGTH length of the corridor, movement time = EFF_LENGTH/FAC_SPEED$\times v_i^0$.

FAC_SPEED How much slower humans move in the corridor (e.g., stairs) compared to the (target) speed v_i^0 in floors.

TO_NODE Where humans are going, when leaving this corridor. To_node can be DOOR, EXIT, CORR, or ENTR.

Note, that CORR is usually used to define stairs between floors: $\mathrm{Door}_{2^{\mathrm{nd}}\ \mathrm{floor}} \rightarrow \mathrm{Corr} \rightarrow \mathrm{Door}_{1^{\mathrm{st}}\ \mathrm{floor}}$. Stairs could also be constructed using the EVSS namelists correctly, but this is not as straight forward as to use CORR constructions.

8.15 The EVSS Namelist Group

Defines an incline (e.g., stairs or spectator stand) or an escalator. The defined 'incline' could also be horizontal. Then it specifies a piece of the current floor at different vertical position than given on the MESH line of the evacuation floor. The z co-ordinates of the EVSS constructions are only used to plot the humans in 'correct' positions when they are viewed by Smokeview. The human movement algorithm uses only the x and y.

ID ID string of the incline.

XB co-ordinates, should define a plane in the (x, y) plane, the z should belong to a main evacuation mesh.

EVAC_MESH If there are overlapping main evacuation meshes then this parameter could be used to specify the mesh where this EVSS line is applied.

IOR direction of the incline, e.g., +1 means that the $+x$ edge of the EVSS plane is touching the main evacuation plane defined by the z of XB.

HEIGHT The height of the incline measured from the level of the main evacuation plane defined by the z of XB. The other edge (opposite to the IOR edge) of the incline has $z = z_{XB} + \mathrm{height}$. HEIGTH can have a positive or a negative value.

HEIGHT0 The height of the base line of the incline measured from the level of the main evacuation plane defined by the z of XB. The IOR edge of the incline has $z = z_{XB} + \mathrm{height0}$. HEIGTH0 can have a positive or a negative value. If *HEIGHT0*=*HEIGHT* the EVSS defines a horisontal plane and IOR has no effect.

FAC_V0_UP The unimpeded speed of a human upwards the plane is $v = FAC_V0_UP \times v_0$.

FAC_V0_DOWN The unimpeded speed of a human downwards the plane is $v = FAC_V0_DOWN \times v_0$.

FAC_V0_HORI The unimpeded speed of a human horisontally along the plane is $v = FAC_V0_HORI \times v_0$.

ESC_SPEED The speed of an escalator. One can use EVSS as a simple model of an escalator, humans are all moving with the velocity ESC_SPEED along the escalator, i.e., they are not overtaking each others or walking on the escalator.

9 Additional FDS+Evac Input Files

The FDS+Evac calculation might have also other input files than the `CHID.fds` file. These files are not needed but they may be used to speed up the calculation and also to separate the fire and evacuation parts of the calculation.

The file `CHID_evac.eff` contains the converged human flow fields, which are calculated at the beginning of the FDS+Evac calculation. If this file exist and there are no fire meshes (`EVACUATION=.FALSE.`), it is read in. Otherwise it is (re)calculated and saved on the disk. This file is useful if one is doing many human egress calculations using exactly the same geometry but with different human input, e.g., varying the number of humans, the democraphics of humans, etc. It is very useful when doing Monte Carlo calculations in a quite complex buildings. One do not need every time to calculate the human flow fields and, thus, one is saving some CPU seconds.

The file `CHID_evac.fed` contains the smoke and gas concentration information from the FDS5 fire calculation. This file is tried to read in, if there are no 'fire' meshes (`EVACUATION=.FALSE.`) specified in the input. If there is at least one 'fire' mesh specified and also at least one main evacuation mesh (`EVAC_HUMANS=.TRUE.` and `EVACUATION=.TRUE.`) specified, then this file is (re)calculated and saved on the disk.

Note, that both files `CHID_evac.eff` and `CHID_evac.fed` are assuming that the evacuation meshes and geometry are exactly the same in the new calculation than was in the one, which wrote the files.

10 FDS+Evac: Output Files

FDS+Evac produces a file `CHID_evac.csv`, which has information on the number of humans on the different floors and stairs at a given time as well as the total number of humans inside the building. The file also list the number of humans gone through each exit and door. The first column is the time and the second column is the number of humans inside the whole building. Then the number of humans in each main evacuation meshes ("floors") and in each corridor/stairs (`CORR` namelists) are given. After these the number of humans gone through various exits and doors are reported. The last three columns are printed only if the FED is used, i.e., the smoke and toxic gas information is available. The first of these columns reports the number of dead humans, i.e., those whose FED values are larger than unity. The next column is the maximum value of FED among all humans, dead or alive. Note, that the FED value of the "dead" humans will continue to build up as if they would be alive. Finally, the last column is the maximum FED value of the humans which are alive.

Human movement may be visualized by Smokeview, where 'Evacuation' is shown on the Load/Save menu. The humans are saved on '.prt5' files. During the run of FDS+Evac lots of evacuation information is printed on the standard error. If you want to save this information, you should redirect the standard error to some file. Read your DOS or Unix/Linux manual how to do this (`2&>1 > CHID.err`).

The file `CHID_evac.eff` contains the converged human flow fields and the file `CHID_evac.fed` contains the smoke and gas concentration information. These might be used later, if more evacuation calculations are done using same geometrical information, e.g., if one is doing a Monte Carlo simulation of the egress scenario.

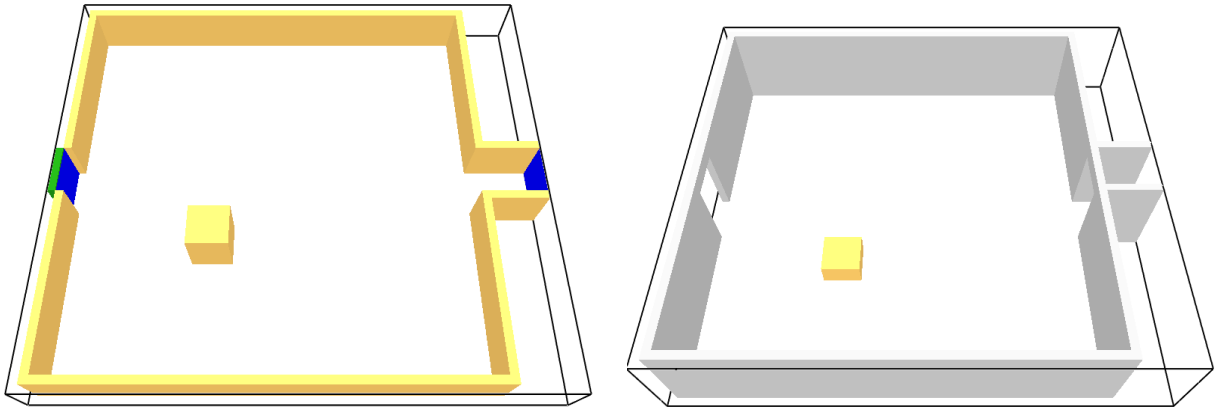

Figure 9: Example 1: Evacuation and fire calculation geometries.

11 Sample Calculation

Below two example inputs files of FDS+Evac are given. These input files are not representing any real building, they are just used to show some of the keywords and parameters, which can be used in FDS+Evac egress calculation.

The first input file specifies a fire in a room with two doors, see Fig. 9. Humans are using both doors and they select the door by using the exit door selection algorithm, thus, each of the two doors needs its own evacuation flow field. This means that one needs to define the main evacuation mesh and two additional door flow field meshes for this case besides the fire mesh.

```
&HEAD CHID='evac_example1', TITLE='Room Evacuation Test'  /

 Fire mesh(es).
&MESH IJK=60,54,12, XB= -0.4,11.6, -0.4,10.4, 0.0,2.4 /

 One floor with 2 exit doors, thus, we need:
     one main evac mesh  (EVACUATION=.TRUE., EVAC_HUMANS=.TRUE.)
     two door flow meshes (EVACUATION=.TRUE., EVAC_HUMANS=.FALSE.)

 Main evacuation mesh for this floor. This mesh contains the humans.
 Evacuation meshes should all have an unique ID string defined.

&MESH IJK=60,54,1, XB= -0.4,11.6, -0.4,10.4, 0.4,1.6,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='MainEvacGrid' /

 Additional door flow fields.
 Note: main evacuation mesh and the door flow meshes should have
 same XB and IJK.

&MESH IJK=60,54,1, XB= -0.4,11.6, -0.4,10.4, 0.4,1.6,
      EVACUATION=.TRUE., ID='LeftExitGrid' /
&MESH IJK=60,54,1, XB= -0.4,11.6, -0.4,10.4, 0.4,1.6,
      EVACUATION=.TRUE., ID='RightExitGrid' /
```

```
&TIME TWFIN=200.0 /

&MISC SURF_DEFAULT='WALL' /

&DUMP NFRAMES=200,
      DT_PART=0.5,
      DT_HRR=1.0,
      DT_SLCF=1.0,
      DT_PL3D=10.0,
      DT_ISOF=10.0 /

&REAC ID         = 'POLYURETHANE'
      FYI        = 'C_6.3 H_7.1 N O_2.1, NFPA Handbook, Babrauskas'
      SOOT_YIELD = 0.10
      N          = 1.0
      C          = 6.3
      H          = 7.1
      O          = 2.1  /

&SURF ID='BURNER', HRRPUA=1000., PART_ID='smoke', COLOR='RASPBERRY' /

&MATL ID            = 'GYPSUM PLASTER'
      FYI           = 'Quintiere, Fire Behavior'
      CONDUCTIVITY  = 0.48
      SPECIFIC_HEAT = 0.84
      DENSITY       = 1440. /

&SURF ID             = 'WALL'
      RGB            = 200,200,200
      MATL_ID        = 'GYPSUM PLASTER'
      THICKNESS      = 0.012 /

&PART ID='smoke', MASSLESS=.TRUE., SAMPLING_FACTOR=1 /

 Ordinary fire calculation geometry input.
&OBST XB= -0.20, 0.00, -0.20, 10.20, 0.00, 2.40 /
&OBST XB= 10.00,10.20, -0.20, 10.20, 0.00, 2.40 /
&OBST XB= -0.20,10.20, -0.20,  0.00, 0.00, 2.40 /
&OBST XB= -0.20,10.20, 10.00, 10.20, 0.00, 2.40 /
&OBST XB= 10.00,11.60,  4.20,  4.40, 0.00, 2.40 /
&OBST XB= 10.00,11.60,  5.60,  5.80, 0.00, 2.40 /
&HOLE XB= -0.21, 0.01,  4.39,  5.61, 0.00, 2.00 /
&HOLE XB=  9.99,10.21,  4.39,  5.61, 0.00, 2.00 /

 The fire as a burner.
&OBST XB= 3.00, 4.00, 3.00, 4.00, 0.00, 0.60, SURF_ID='INERT' /
&VENT XB= 3.00, 4.00, 3.00, 4.00, 0.60, 0.60, SURF_ID='BURNER',
```

```
      EVACUATION=.FALSE. /

 Note, that EVACUATION=.FALSE. should be given for 'MB' vents or
 otherwise these vent are introduce also to the evacuation geometry.
&VENT MB='YMIN',SURF_ID='OPEN', EVACUATION=.FALSE. /
&VENT MB='YMAX',SURF_ID='OPEN', EVACUATION=.FALSE. /

 Evacuation geometry input.

 Fire geometry holes should be duplicated, if they are also wanted
 to show up in the evacuation geometry.
&HOLE XB= -0.21, 0.01,  4.39,  5.61, 0.00, 2.00, EVACUATION=.TRUE./
&HOLE XB=  9.99,10.21,  4.39,  5.61, 0.00, 2.00, EVACUATION=.TRUE./

 A fan boundary condition is used to calculate the evacuation
 flow fields.
&SURF ID = 'OUTFLOW', VEL = +0.00001, TAU_V=0.1 /

 Define the evacuation vents for the main evacuation mesh, there
 should be an evacuation vent at every place, where humans can
 go 'inside' some door, exit, etc object.

 This vent is not at an outer boundary of the domain nor at a solid
 object, thus, there should be an OBST behind it.
 Left Exit:
&VENT XB= -0.20,-0.20,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='MainEvacGrid', EVACUATION=.TRUE., RGB=0,0,255 /
&OBST XB= -0.40,-0.20,  4.40,5.60, 0.40,1.60, SURF_ID='INERT',
      EVACUATION=.TRUE., RGB=30,150,20 /

This vent is at the outer boundary of the domain, i.e., it is
 on a solid object, thus, no need for an OBST behind it.
 Right Exit:
&VENT XB= 11.60,11.60,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='MainEvacGrid', EVACUATION=.TRUE., RGB=0,0,255/

 An exit namelist defines an exit door which takes humans out of the
 calculation.
&EXIT ID='LeftExit', IOR=-1,
      FYI= 'Comment line',
      VENT_FFIELD='LeftExitGrid',
      XYZ= 0.20, 5.00, 1.50,
      XB= -0.20,-0.20,  4.40,5.60, 0.40,1.60 /
&VENT XB= -0.20,-0.20,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='LeftExitGrid', EVACUATION=.TRUE./ Left Exit Fan

&EXIT ID='RightExit', IOR=+1,
      FYI= 'Comment line',
```

```
      VENT_FFIELD='RightExitGrid',
      XYZ= 9.80, 5.00, 1.50,
      XB= 11.60,11.60,  4.40,5.60, 0.40,1.60 /
&VENT XB= 11.60,11.60,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='RightExitGrid', EVACUATION=.TRUE./ Right Exit Fan

 Next is just a counter.
&EXIT ID='RightCounter', IOR=+1,
      FYI= 'Comment line',
      COUNT_ONLY=.TRUE.,
      XB= 10.00,10.00,  4.40,5.60, 0.40,1.60 /

 Evacuation calculation, human properties
 Note: Parameters DENS_INIT and COLOR_METHOD affect all humans and
       the values read in from the last '&PERS' line where they
       exits are used for all humans.
&PERS ID='Adult',
        FYI='Male+Female diameter and velocity',
        DEFAULT_PROPERTIES='Adult',
        PRE_EVAC_DIST=1,
        PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
        DET_EVAC_DIST=1,
        DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0,
        DENS_INIT=4.0
        COLOR_METHOD = 7 /

&PERS ID='Male',
        FYI='Male diameter and velocity',
        DEFAULT_PROPERTIES='Male',
        PRE_EVAC_DIST=1,
        PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
        DET_EVAC_DIST=1,
        DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

&PERS ID='Female',
        FYI='Female diameter and velocity',
        DEFAULT_PROPERTIES='Female',
        PRE_EVAC_DIST=1,
        PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
        DET_EVAC_DIST=1,
        DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

&PERS ID='Child',
        FYI='Child diameter and velocity',
        DEFAULT_PROPERTIES='Child',
        PRE_EVAC_DIST=1,
        PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
        DET_EVAC_DIST=1,
```

```
        DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

&PERS ID='Elderly',
        FYI='Elderly diameter and velocity',
        DEFAULT_PROPERTIES='Elderly',
        PRE_EVAC_DIST=1,
        PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
        DET_EVAC_DIST=1,
        DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

 Initial positions of the humans

 These humans will go to the left exit, if it is not blocked by smoke.
&EVAC   ID = 'HumanLeftDoorKnown',
        NUMBER_INITIAL_PERSONS = 25,
        XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
        QUANTITY = 'BLUE',
        KNOWN_DOOR_NAMES = 'LeftExit',
        KNOWN_DOOR_PROBS = 1.0,
        PERS_ID = 'Male' /

 These humans will go to the right exit, if it is not blocked by smoke.
&EVAC   ID = 'HumanRightDoorKnown',
        NUMBER_INITIAL_PERSONS = 25,
        XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
        QUANTITY = 'RED',
        KNOWN_DOOR_NAMES = 'RightExit',
        KNOWN_DOOR_PROBS = 1.0,
        PERS_ID = 'Female' /

 These humans know both doors so they will use the nearest visible
 known door which is not blocked by smoke.
&EVAC   ID = 'HumanBothDoorsKnown',
        NUMBER_INITIAL_PERSONS = 25,
        XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
        QUANTITY = 'GREEN',
        KNOWN_DOOR_NAMES = 'LeftExit','RightExit',
        KNOWN_DOOR_PROBS = 1.0,1.0,
        PERS_ID = 'Child' /

 These humans do not have a known door and they will try to go to the
 nearest visible exit door.
&EVAC   ID = 'HumanNoDoorKnown',
        NUMBER_INITIAL_PERSONS = 25,
        XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
        QUANTITY = 'BLACK',
        PERS_ID = 'Adult' /
```

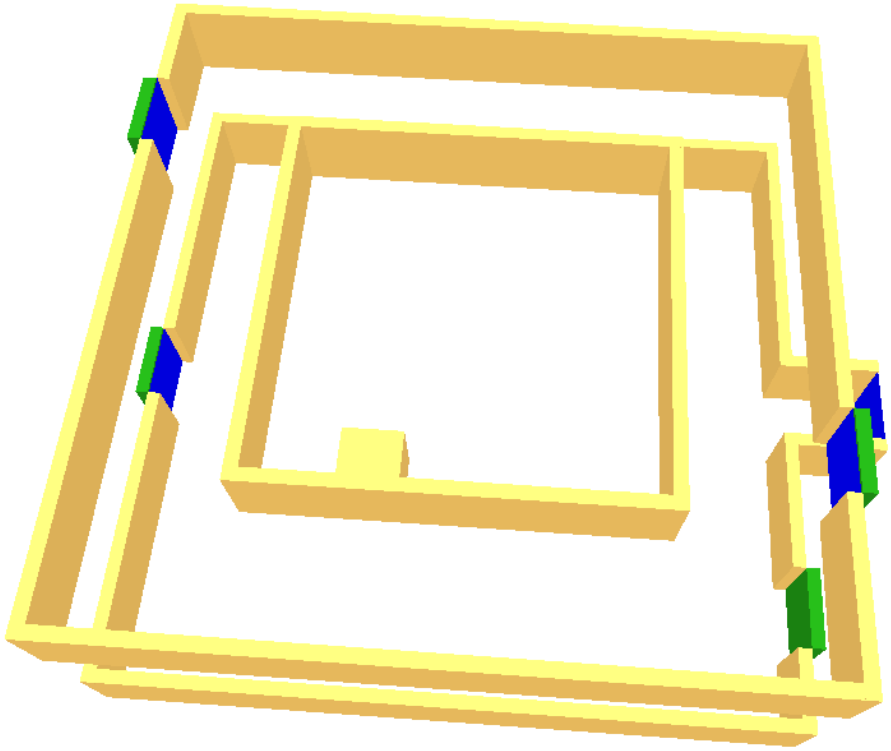

Figure 10: Example 2: Evacuation calculation geometry.

```
 An evacuation hole, e.g., do not put humans on top of the fire.
&EVHO   ID = 'Evho_Fire',
        FYI = 'Do not put humans close to the fire',
        XB = 2.0,5.0, 2.0,5.0, 0.4,1.6 /

 Fire calculation output.
&BNDF QUANTITY='WALL_TEMPERATURE' /
&SLCF PBX=2.40, QUANTITY='TEMPERATURE' /

 Evacuation output used to plot the evacuation flow fields.
&SLCF PBZ = 1.500, QUANTITY = 'VELOCITY', VECTOR = .TRUE. /

&TAIL /
```

The second input file specifies a two-floor building, see Fig. 10, each floor consisting of one human movement area, i.e., only one main evacuation mesh per floor is needed. There is a fire in downstairs and the smoke is going to the second floor by an opening at the ceiling. The second floor is connected to the first floor in the egress calculation, i.e., the second floor humans are transfered to the first floor by the combination of doors and stairs. The second floor has two exit doors, one leading to the stairs going to the first floor (the right exit) and one leading to the stairs leading directly to outside of the building (the left exit). The first floor has two exit doors.

```
&HEAD CHID='evac_example2', TITLE='2 Floor Evacuation Test'  /

 Fire mesh(es).
&MESH IJK=54,50,25, XB= -0.2,10.6,  0.0,10.0, 0.0,5.0 /

 Main evacuation meshes for the floors. These meshes contains the
 humans. Evacuation meshes should all have an unique ID string
 defined.

&MESH IJK=60,54,1, XB= -0.4,11.6, -0.4,10.4, 0.4,1.6,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='MainEvacGrid' /
&MESH IJK=54,54,1, XB= -0.4,10.4, -0.4,10.4, 3.0,4.2,
      EVACUATION=.TRUE., EVAC_HUMANS=.TRUE., ID='MainEvacGrid2' /

 Additional door flow fields.
 Note: main evacuation grid and the door flow grids should have
 same XB and IJK.

&MESH IJK=60,54,1, XB= -0.4,11.6, -0.4,10.4, 0.4,1.6,
      EVACUATION=.TRUE., ID='LeftExitGrid' / Left, 1st floor
&MESH IJK=60,54,1, XB= -0.4,11.6, -0.4,10.4, 0.4,1.6,
      EVACUATION=.TRUE., ID='RightExitGrid' / Right, 1st floor

&MESH IJK=54,54,1, XB= -0.4,10.4, -0.4,10.4, 3.0,4.2,
      EVACUATION=.TRUE., ID='LeftDoorGrid2' / Left, 2nd floor
&MESH IJK=54,54,1, XB= -0.4,10.4, -0.4,10.4, 3.0,4.2,
      EVACUATION=.TRUE., ID='RightDoorGrid2' / Right, 2nd floor

&TIME TWFIN=200.0 /

&MISC SURF_DEFAULT='WALL' /

&DUMP NFRAMES=200,
      DT_PART=0.5,
      DT_HRR=1.0,
      DT_SLCF=1.0,
      DT_PL3D=10.0,
      DT_ISOF=10.0 /

&REAC ID         = 'POLYURETHANE'
      FYI        = 'C_6.3 H_7.1 N O_2.1, NFPA Handbook, Babrauskas'
      SOOT_YIELD = 0.10
      N          = 1.0
      C          = 6.3
      H          = 7.1
      O          = 2.1  /

&SURF ID='BURNER', HRRPUA=1000., PART_ID='smoke', COLOR='RASPBERRY' /
```

```
&MATL ID            = 'GYPSUM PLASTER'
      FYI           = 'Quintiere, Fire Behavior'
      CONDUCTIVITY  = 0.48
      SPECIFIC_HEAT = 0.84
      DENSITY       = 1440. /

&SURF ID             = 'WALL'
      RGB            = 200,200,200
      MATL_ID        = 'GYPSUM PLASTER'
      THICKNESS      = 0.012 /

&PART ID='smoke', MASSLESS=.TRUE., SAMPLING_FACTOR=1 /

 Ordinary fire calculation geometry input.
&OBST XB= -0.20,10.20, -0.20, 10.20, 2.40, 2.60 / floor
&HOLE XB=  2.20, 7.80,  2.20,  7.80, 2.39, 2.61 / floor hole
&OBST XB=  2.00, 8.00,  2.00,  2.20, 2.60, 3.60 / balustrade
&OBST XB=  2.00, 8.00,  7.80,  8.00, 2.60, 3.60 / balustrade
&OBST XB=  2.00, 2.20,  2.00,  8.00, 2.60, 3.60 / balustrade
&OBST XB=  7.80, 8.00,  2.00,  8.00, 2.60, 3.60 / balustrade
&OBST XB= 10.20,11.60,  4.20,  5.80, 2.40, 2.60 / floor

&OBST XB= -0.20, 0.00, -0.20, 10.20, 0.00, 5.00 /
&OBST XB= 10.00,10.20, -0.20, 10.20, 0.00, 5.00 /
&OBST XB= -0.20,10.20, -0.20,  0.00, 0.00, 5.00 /
&OBST XB= -0.20,10.20, 10.00, 10.20, 0.00, 5.00 /
&OBST XB= 10.00,11.60,  4.20,  4.40, 0.00, 2.40 / Right Corridor Wall
&OBST XB= 10.00,11.60,  5.60,  5.80, 0.00, 2.40 / Right Corridor Wall
&HOLE XB= -0.21, 0.01,  4.39,  5.61, 0.00, 2.00 / Left Door
&HOLE XB=  9.99,10.21,  4.39,  5.61, 0.00, 2.00 / Right Door Hole

 The fire as an burner.
&OBST XB= 3.00, 4.00, 3.00, 4.00, 0.00, 0.60, SURF_ID='INERT' /
&VENT XB= 3.00, 4.00, 3.00, 4.00, 0.60, 0.60, SURF_ID='BURNER',
      EVACUATION=.FALSE. /

 Note, that EVACUATION=.FALSE. should be given for 'MB' vents or
 otherwise these vent are introduce also to the evacuation geometry.
&VENT MB='YMIN',SURF_ID='OPEN', EVACUATION=.FALSE. /
&VENT MB='YMAX',SURF_ID='OPEN', EVACUATION=.FALSE. /

 Evacuation geometry input.

 Fire geometry holes should be duplicated, if they are also wanted
 to show up in the evacuation geometry.
&HOLE XB= -0.21, 0.01,  4.39,  5.61, 0.00, 2.00, EVACUATION=.TRUE./
&HOLE XB=  9.99,10.21,  4.39,  5.61, 0.00, 2.00, EVACUATION=.TRUE./
```

```
&HOLE XB= -0.21, 0.01,  7.39,  8.61, 2.60, 4.60, EVACUATION=.TRUE. /
&HOLE XB=  9.99,10.21,  2.39,  3.61, 2.60, 4.60, EVACUATION=.TRUE. /

 A fan boundary condition is used to calculate the evacuation
 flow fields.
&SURF ID = 'OUTFLOW', VEL = +0.00001, TAU_V=0.1 /

 Define the evacuation vents for the main evacuation meshes, there
 should be an evacuation vent at every place, where humans can
 go 'inside' some door, exit, etc object.

 This vent is not at an outer boundary of the domain nor at a solid
 object, thus, there should be an OBST behind it.
 Left Exit, 1st Floor:
&VENT XB= -0.20,-0.20,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='MainEvacGrid', EVACUATION=.TRUE., RGB=0,0,255 /
&OBST XB= -0.40,-0.20,  4.40,5.60, 0.40,1.60,
      EVACUATION=.TRUE., RGB=30,150,20 /

 This vent is at the outer boundary of the domain, i.e., it is
 on a solid object, thus, no need for an OBST behind it.
 Right Exit, 1st Floor:
&VENT XB= 11.60,11.60,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='MainEvacGrid', EVACUATION=.TRUE., RGB=0,0,255 /

 This vent is not at an outer boundary of the domain nor at a solid
 object, thus, there should be an OBST behind it.
 Right Exit, 2nd Floor:
&VENT XB= 10.20,10.20,  2.40,3.60, 3.0,4.2, SURF_ID='OUTFLOW',
      MESH_ID='MainEvacGrid2', EVACUATION=.TRUE., RGB=0,0,255 /
&OBST XB= 10.20,10.40,  2.40,3.60, 3.0,4.2,
      EVACUATION=.TRUE., RGB=30,150,20 / Right Door, 2nd

 This vent is not at an outer boundary of the domain nor at a solid
 object, thus, there should be an OBST behind it.
 Left Exit, 2nd Floor:
&VENT XB= -0.20,-0.20,  7.40,8.60, 3.0,4.2, SURF_ID='OUTFLOW',
      MESH_ID='MainEvacGrid2', EVACUATION=.TRUE., RGB=0,0,255 /
&OBST XB= -0.40,-0.20,  7.40,8.60, 3.0,4.2,
      EVACUATION=.TRUE., RGB=30,150,20 / Left Door, 2nd

 An exit namelist defines an exit door which takes humans out
 of the calculation.
&EXIT ID='LeftExit', IOR=-1,
      FYI= 'Comment line',
      VENT_FFIELD='LeftExitGrid',
      XYZ= 0.20, 5.00, 1.50,
```

```
      XB= -0.20,-0.20,  4.40,5.60, 0.40,1.60 /
&VENT XB= -0.20,-0.20,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='LeftExitGrid', EVACUATION=.TRUE./ Left Exit Fan

&EXIT ID='RightExit', IOR=+1,
      FYI= 'Comment line',
      VENT_FFIELD='RightExitGrid',
      XYZ= 9.80, 5.00, 1.50,
      XB= 11.60,11.60,  4.40,5.60, 0.40,1.60 /
&VENT XB= 11.60,11.60,  4.40,5.60, 0.40,1.60, SURF_ID='OUTFLOW',
      MESH_ID='RightExitGrid', EVACUATION=.TRUE./ Right Exit Fan

 Next is just a counter.
&EXIT ID='RightCounter', IOR=+1,
      FYI= 'Comment line',
      COUNT_ONLY=.TRUE.,
      XB= 10.00,10.00,  4.40,5.60, 0.40,1.60 /

 Second floor doors etc.

 This is a combination of a door leading to a stairs, which is
 leading directly to outside of the building:
 DOOR ==> CORR ==> EXIT combination.
&DOOR ID='LeftDoor2nd', IOR=-1,
      FYI= 'Comment line',
      VENT_FFIELD='LeftDoorGrid2',
      TO_NODE= 'LeftCorr'
      XYZ= 0.0, 8.00, 3.6,
      XB= -0.20,-0.20,  7.40,8.60, 3.0,4.2 /
&VENT XB= -0.20,-0.20,  7.40,8.60, 3.0,4.2 SURF_ID='OUTFLOW',
      MESH_ID='LeftDoorGrid2', EVACUATION=.TRUE./ Left Door Fan, 2nd
&CORR ID='LeftCorr',
      FYI='Comments',
      MAX_HUMANS_INSIDE=20,
      EFF_LENGTH= 8.5,
      FAC_SPEED=0.7,
      TO_NODE='LeftCorrExit' /
&EXIT ID='LeftCorrExit',
      FYI='A dummy exit, the end point to a corridor object',
      IOR=-1,
      XB= -0.40,-0.40,  7.40,8.60, 0.40,1.60 /

 This is a combination of a door leading to a stairs, which is
 leading to the first floor: DOOR ==> CORR ==> ENTR combination.
&DOOR ID='RightDoor2nd', IOR=+1,
      FYI= 'Comment line',
      VENT_FFIELD='RightDoorGrid2',
      TO_NODE= 'RightCorr'
```

```
      XYZ=10.0, 3.00, 3.6,
      XB= 10.20,10.20,  2.40,3.60, 3.0,4.2 /
&VENT XB= 10.20,10.20,  2.40,3.60, 3.0,4.2, SURF_ID='OUTFLOW',
      MESH_ID='RightDoorGrid2', EVACUATION=.TRUE./
&CORR ID='RightCorr',
      FYI='Comments',
      MAX_HUMANS_INSIDE=20,
      EFF_LENGTH= 8.5,
      FAC_SPEED=0.7,
      TO_NODE='RightEntry' /
&ENTR ID='RightEntry',
      FYI='Comments',
      IOR=-1,
      XB=10.20,10.20,  1.00,2.20,  0.40,1.60 /
&HOLE XB= 9.99,10.20,  1.00,2.20,  0.40,1.60,
      EVACUATION=.TRUE., RGB=30,150,20 / 1st Floor Entry
&OBST XB=10.20,10.40,  1.00,2.20,  0.40,1.60,
      EVACUATION=.TRUE., RGB=30,150,20 / 1st Floor Entry

 Evacuation calculation, human properties
 Note: Parameters DENS_INIT and COLOR_METHOD affect all humans and
       the values read in from the last '&PERS' line where they
       exits are used for all humans.
&PERS ID='Adult',
      FYI='Male+Female diameter and velocity',
      DEFAULT_PROPERTIES='Adult',
      PRE_EVAC_DIST=1,
      PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
      DET_EVAC_DIST=1,
      DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0,
      DENS_INIT= 4.0,
      COLOR_METHOD = 0 /

&PERS ID='Male',
      FYI='Male diameter and velocity',
      DEFAULT_PROPERTIES='Male',
      PRE_EVAC_DIST=1,
      PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
      DET_EVAC_DIST=1,
      DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

&PERS ID='Female',
      FYI='Female diameter and velocity',
      DEFAULT_PROPERTIES='Female',
      PRE_EVAC_DIST=1,
      PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
      DET_EVAC_DIST=1,
      DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /
```

```
&PERS ID='Child',
      FYI='Child diameter and velocity',
      DEFAULT_PROPERTIES='Child',
      PRE_EVAC_DIST=1,
      PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
      DET_EVAC_DIST=1,
      DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

&PERS ID='Elderly',
      FYI='Elderly diameter and velocity',
      DEFAULT_PROPERTIES='Elderly',
      PRE_EVAC_DIST=1,
      PRE_MEAN=10.0,PRE_LOW=5.0,PRE_HIGH=15.0,
      DET_EVAC_DIST=1,
      DET_MEAN=10.0,DET_LOW=5.00,DET_HIGH=15.0 /

 Initial positions of the humans

 1st Floor:
 These humans will go to the left exit, if it is not blocked by smoke.
&EVAC ID = 'HumanLeftDoorKnown',
      NUMBER_INITIAL_PERSONS = 25,
      XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
      QUANTITY = 'BLUE',
      KNOWN_DOOR_NAMES = 'LeftExit',
      KNOWN_DOOR_PROBS = 1.0,
      PERS_ID = 'Male' /

 These humans will go to the right exit, if it is not blocked by smoke.
&EVAC ID = 'HumanRightDoorKnown',
      NUMBER_INITIAL_PERSONS = 25,
      XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
      QUANTITY = 'RED',
      KNOWN_DOOR_NAMES = 'RightExit',
      KNOWN_DOOR_PROBS = 1.0,
      PERS_ID = 'Female' /

 These humans know both doors so they will use the nearest visible
 known door which is not blocked by smoke.
&EVAC ID = 'HumanBothDoorsKnown',
      NUMBER_INITIAL_PERSONS = 25,
      XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
      QUANTITY = 'GREEN',
      KNOWN_DOOR_NAMES = 'LeftExit','RightExit',
      KNOWN_DOOR_PROBS = 1.0,1.0,
      PERS_ID = 'Child' /
```

```
 These humans do not have a known door and they will try to go to
 the nearest visible exit door.
&EVAC ID = 'HumanNoDoorKnown',
      NUMBER_INITIAL_PERSONS = 25,
      XB = 1.0,9.0,  1.0,9.0, 0.4,1.6
      QUANTITY = 'BLACK',
      PERS_ID = 'Adult' /

 2nd Floor:
 All of these humans know the right door on the 2nd floor and the
 right exit on the first floor. On the average, only 50 \% know
 the left door on the second floor and none knows the left exit
 on the first floor.
&EVAC ID = 'Human2ndFloor',
      NUMBER_INITIAL_PERSONS = 50,
      XB = 0.5,9.5,  0.5,9.5, 3.0,4.2
      QUANTITY = 'MAGENTA',
      KNOWN_DOOR_NAMES = 'LeftDoor2nd','RightDoor2nd','RightExit',
      KNOWN_DOOR_PROBS = 0.5,1.0,1.0,
      PERS_ID = 'Adult' /

 An evacuation hole, e.g., do not put humans on top of the fire.
&EVHO ID = 'Evho_Fire',
      FYI = 'Do not put humans close to the fire',
      XB = 2.0,5.0, 2.0,5.0, 0.4,1.6 /

 An evacuation hole, e.g., do not put humans on top of the opening
 in the ceiling.
&EVHO ID = 'Evho_2ndFloor',
      FYI = 'atrium space',
      XB = 2.0,8.0, 2.0,8.0, 3.0,4.2 /

 Fire calculation output.
&BNDF QUANTITY='WALL_TEMPERATURE' /
&SLCF PBX=2.40, QUANTITY='TEMPERATURE' /

 Evacuation output used to plot the evacuation flow fields.
&SLCF PBZ = 1.000, QUANTITY = 'VELOCITY', VECTOR = .TRUE. /
&SLCF PBZ = 3.600, QUANTITY = 'VELOCITY', VECTOR = .TRUE. /

&TAIL /
```

12 Conclusion

The FDS+Evac is under construction. The next things to be implemented are:

- Merging flows in corridors and stairs.
- A more realistic `CORR` object: Record the position of each human inside the corridor/stairs and use the equations of motion to model the movement in the corridor/stairs.
- More pre-defined human classes, especially those refered in the IMO circular [21].
- Elevators.
- More intelligence in the exit door selection algorithm, e.g., estimated queueing time due to the other humans heading towards the same exit door.
- Social interactions like herding etc.
- Sreading of the information: human to human communication.
- Some support to the parallel version of the FDS5: The fire related information (the CHID_evac.fed file) should be saved when doing parallel calculation.
- Easier generation of the input file.

The present status of the FDS+Evac is:

- Smoke vs walking speed correlations are included.
- Fractional Effective Dose is calculated and used to 'incapacitate' humans.
- Smoke density can be used to trigger human movement.
- Simple exit door selection algorithm is implemented.
- Inclines, stairs, escalators can be modelled explicitely by using the equations of motion for each person.
- Simple stair algorithm without merging flows. If there are merging flows in staris then these should be modelled explicitely, which means some additional work to construct the input file.
- The flows through doors, stairs and corridors are reproduced nicely by the underlaying dynamics.
- Congestion can be studied.
- The effect of the many input parameters of the human movement model are understood well and their effect on the human flows is known.

The shortcomings of FDS+Evac are:

- Geometry and the calculational mesh, i.e., rectanglular objects, whose edges are along the x and y, are the main elements used to construct the geometry, including inclines and stairs.
- Merging flows in stairs are not easy to model.
- No elevators.

- Evacuation calculations can only be done by the serial version of the FDS5 executable.
- Visualization of the evacuation objects, like exits, door, etc., on the Smokeview window.
- The user input is not easy to give, i.e., no support for importing CAD drawings etc.

Users should notice that the evacuation part of FDS5 is under development, and the features and user input may change in the future.

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